ENDANGERED WHALE SURVEYS OF THE NAVARIN BASIN, ALASKA

by

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ABSTRACT

Density, distribution, and habitat use of endangered species of whales in the Navarin Basin planning unit of the Bering Sea were determined during four seasonal surveys between 1982-83. Vessel and aerial surveys were conducted along systematic tracklines randomly distributed over the outer continental shelf, slope, and rise. Right, gray, fin, and bowhead whales were encountered during approximately 5,500 nautical miles (nm) of aerial and 2,500 nm of vessel surveys completed in the 54,078 nm^2 Navarin Basin. Right whales were observed only during the summer and gray whales only during the fall. Fin whales were present during all four seasons. Gray, fin, and right whales were distributed in the outer continental shelf waters in significantly higher numbers than in the slope or rise waters. Observed densities were 10.7, 6.2, and 1.1 animals per 1,000 nm^2 for gray, fin, and right whales, respectively. Bowhead whales wintered in the marginal ice front, which closely corresponded to the southern limit of the outer continental shelf. They were particularly prevalent in the fringe areas of ice adjacent to the St. Matthew Island polynya. Observed density of this species in the marginal ice front was 10.4 animals per 1,000 nm^2. One group of six fin whales was observed in the southern edge of the ice front. No calves were observed with the four endangered whale species. The results confirm that the Navarin Basin is a feeding area for gray, fin, and possibly right whales during the ice-free period and a wintering area for bowhead and fin whales during the seasonal ice period. The open water of the St. Matthew Island polynya may function as a refuge to bowheads from heavy sea ice, while the shallow shelf waters provide access to food organisms commensurate with the diving characteristics of the other species. Densities of endangered whales in the Basin appear to be variable to other areas within their range. Other whales recorded in the Basin were beluga, minke, and killer whales, and DalI’s porpoises.

INTRODUCTION

Little information is available on whale utilization of the northcentral Bering Sea, particularly in the Navarin Basin. Most information derives from catch (Aldrich 1889, Cook 1926, Townsend 1935, and Tomilin 1957) and scouting (Berzin and Rovnin 1966, Nishiwaki 1974, and Wada 1981) expeditions by commercial whaling vessels. Since the cessation of commercial whaling in the Bering Sea during the 1960s, new information has been largely limited to the National Marine Fisheries Service's Platforms of Opportunity Program (Consiglieri and Bouchet 1981). This program relies on vessels of opportunity collecting marine mammal data primarily on species composition and distribution in the Bering Sea and elsewhere. The only, recent dedicated study of whales was conducted by Brueggeman (1982), who examined bowhead whale abundances distribution, and habitat use in the northcentral Bering Sea, including the Navarin Basin, during early spring. Few additional studies have been conducted in this remote area because of the high costs and difficult logistics required to study it.

Based on the historic and recent literature, at least five of the world's ten species of baleen whales seasonally inhabit the Navarin Basin. Three of these species--fin (<u>Balaenoptera physalus</u>), gray (<u>Eschrichtius robustus</u>), and right (<u>Balaena glacialis</u>) whales--migrate from lower latitudes to feed in the Basin during the ice-free period (Tomil in 1957, Berzin and Rovnin 1966, Rice and Wolman 1971, Rice 1974; Votrogov and Ivashin 1980, Marquette and Braham 1982). Conversely, bowhead whales (<u>Balaena mysticetus</u>) migrate from northern latitudes to winter in the Basin during the seasonal ice period (Braham et al. 1980, Brueggeman 1982). Theminke whale (<u>Balaenoptera acutorostrata</u>) also occurs in the Basin and is probably present yearlong in varying numbers (Tomi 1 in 1957, S1 eptsov 1961, Ivashin and Votrogov 1981). Al 1 of these whales, except the minke whale, are classified as endangered species throughout their range (U.S. Dept. Comm. 1979). Other whales occurring in the Basin are the beluga (<u>Delphinapterus leucas</u>), killer whale

(Orcinus orca), DalI's porpoise (Phocoenoides dalli), and possibly some beaked whales. Sperm (Physeter macrocephalus), sei (Balaenoptera borealis) and humpback (Megaptera novaeangliae) whales, while found in the Bering Sea, primarily occur south of the Navarin Basin (Berzin and Rovnin 1966, Wada 1981).

Stock sizes of these species in the Bering Sea are poorly known. General estimates are available, however, for the North Pacific Ocean including the Bering Sea (Table 1). Of the baleen whales, the fin whale stock is the largest; it is estimated at 21,000 to 29,000 animals (Gambell 1976). Gray whales of the eastern Pacific stock number 13,600 to 19,400 animals (Reilly et al. 1980), while Pacific right whales number only 100-200 animals (Gambell 1976). The proportion of these stocks using the Bering Sea is uncertain. Estimated number of bowhead and beluga whales which winter in the Bering Sea are more certain. Best estimates indicate that approximately 3,390 to 4,325 bowheads (IWC 1983) and 15,000 to ?8,000 beluga (Lowry et al. 1982) whales winter in the Bering Sea (Braham et al. 1977). The largest cetacean stock in the Bering Sea is the Dan's porpoise, which is estimated at 97,000 to 147,000 animals (Bouchet 1982). Estimates are not available for killer or beaked whales. The proportion of whales from these various populations using the Navarin Basin planning unit has not been determined.

The Navarin Basin is scheduled for petroleum exploration and development in 1984. The Endangered Species Act of 1973 and the Outer Continental Shelf Lands Act of 1978 mandate that studies be conducted to determine whether these proposed habitat alterations will have any adverse effects on populations of endangered species of marine mamma 1s. In 1982, the National Oceanic and Atmospheric Administration awarded Envirosphere Company a contract to develop baseline data on endangered and other marine mammals in the Navarin Basin for assessing potential petroleum development impacts on these species. The objectives of the contract were:

TABLE 1

ESTIMATED STOCK SIZES OF CETACEAN SPECIES
FOUND IN THE NORTHCENTRAL BERING SEA

Species	Stock location[a/]	Estimated size	Source
Fin whale	N. Pacific Ocean	21,000 to 29,000[b/]	Gambell (1976)
Gray whale	N. Pacific Ocean	16,500 $\pm$ 2,900[c/]	Reilly et al. (1980)
Bowhead whale	W. Arctic Ocean	3,8572468	International Whaling Commission (1983)
Right whale	N. Pacific Ocean	150 $\pm$ 50	Gambell (1976)
Bel uga	U. Arctic Ocean	15,000 to 18,000	Lowry et al. (1982)
Dan's porpoise	Bering Sea	122,000 $\pm$ 25,000	Bouchet (1982)

a/ N. Pacific and W. Arctic ocean estimates include the Bering Sea.

b/ Fin whale estimate includes Asiatic and N. American stocks.

c/ Gray whale estimate is composed only of E. Pacific Ocean stock.

1. Assess winter habitat use of the Navarin Basin by cetaceans, emphasizing the seasonal population size and distribution of bowhead whales relative to ice and other environmental parameters;

2. Assess habitat use by endangered species of whales during the ice-free season. Identify and enumerate the endangered species of whales in the Basin and correlate their temporal and spatial distribution with environmental parameters; and

3. Document sightings of other species of marine mammals observed during the surveys, and provide estimates of their abundance and distribution within the region.

Objectives 1 and 2 are fully addressed in this report. Objective 3 is treated for cetaceans (whales, dolphins, and porpoises). A second report (Brueggeman and Grotefendt 1984) addresses pinnipeds (seals, sea lions, and walruses) in the Navarin Basin that fulfills Objective 3.

ACKNOWLEDGEMENTS

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STUDY AREA

The Navarin Basin planning unit (hereafter referred to as the Navarin Basin) is located in the northcentral Bering Sea, approximately 200 nautical miles (rim) off the coast of Alaska [Figure 1). It covers over 54,000 nm^2, an area approaching the size of the State of Michigan, and is bound by the U.S.-U.S.S.R. Convention Line to the west, 174°W longitude to the east, and latitudes 63″N and 58″N to the north and south. Water depth in the Basin ranges from about 44 m on the outer continental shelf to over 3,000 m outside the shelf. The shelf comprises approximately half of the total area in the Basin, while the continental slope and rise comprise 36 percent and 14 percent, respectively. There are no islands.

The climate of the Basin features harsh environmental conditions that promote the seasonal development of sea ice (Figure 2). The environmental conditions typically consist of cold temperatures, high wind speeds, poor visibility, and extreme ranges in day length (Brewer et al. 1977). Average annual air temperature and wind speed are O“C and 14 kt yearling, and visibility less than 2 nm persists approximately 14 percent of the time during the year. Temperatures are coldest during the early spring when wind velocities are lowest. Wind velocities exceeding 20 kt are most frequent in the fall when visibility is poorest; the best visibility conditions occur in the winter but daylength is less than 6 hours.

Sea ice persists in the Navarin Basin from December through June (Potocsky 1975). Ice coverage of the Basin is greatest from February through April. It seldom extends south of the outer continental shelf and is typically less than 1 m thick. Breakup of the sea ice begins in mid-April, and the Basin is generally ice-free by late June. The combination of sea ice, harsh environmental conditions, and remoteness demonstrate the difficulties of surveying marine mammals in the Navarin Basin.

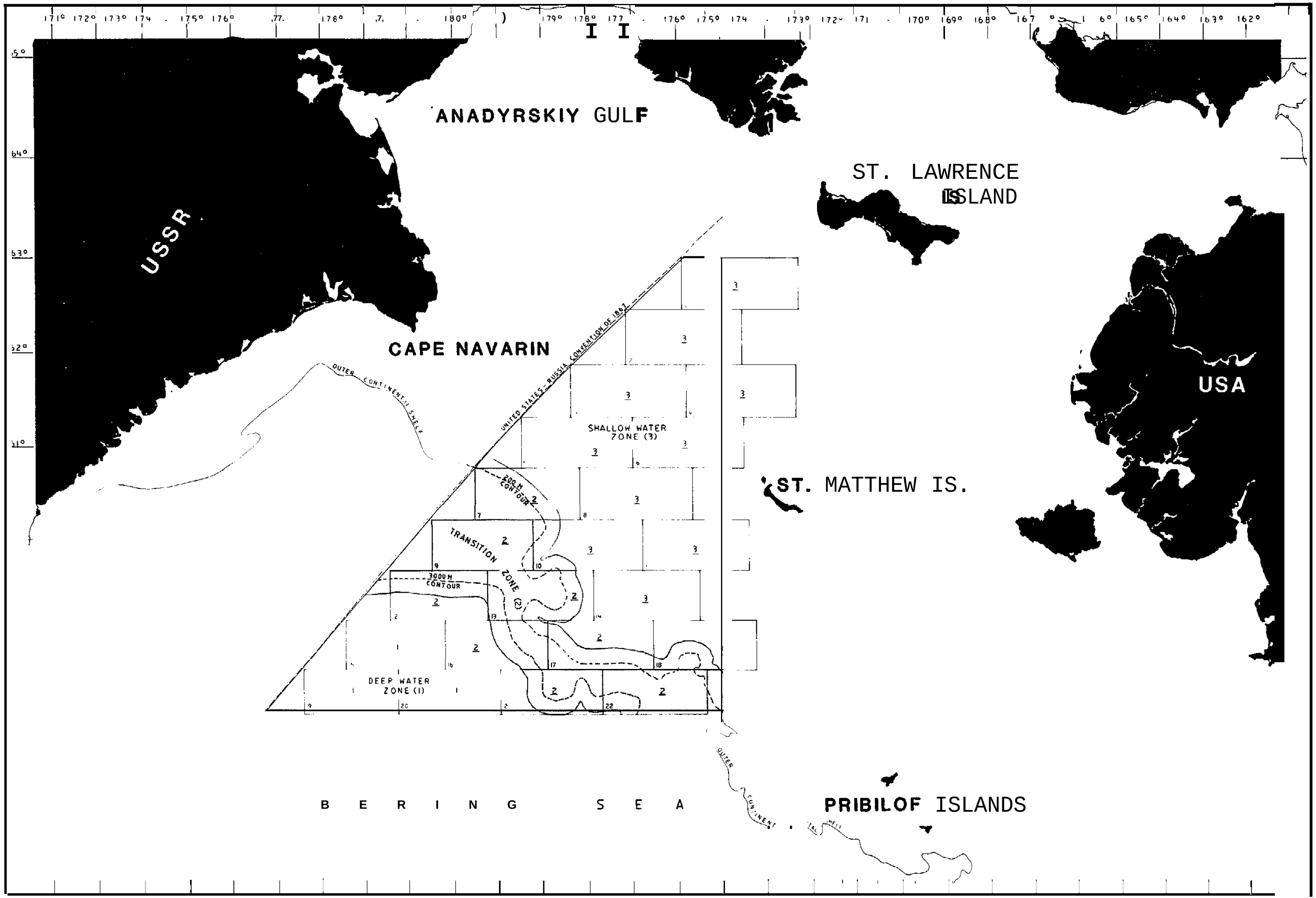

FIGURE 1 STUDY AREA AND SAMPLING DESIGN IN THE NAVARIN BASIN FOR SPRING THROUGH FALL SURVEY PERIOD, 1982.

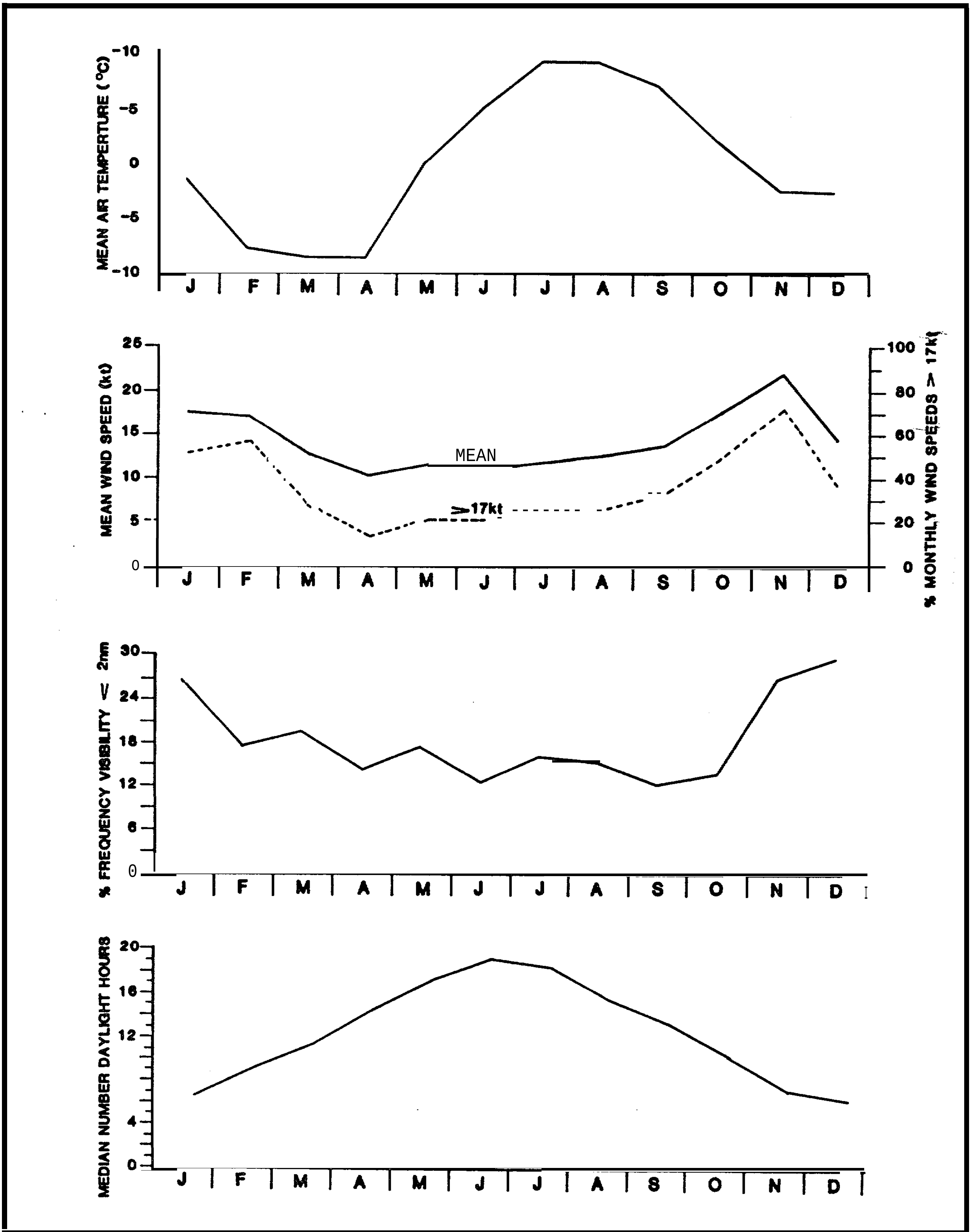

FIGURE 2 HISTORIC ENVIRONMENTAL CONDITIONS OF THE NORTH CENTRAL BERING SEA (**BROWER** ET AL. 19779.

METHODS

Two sampling designs were developed for aerial and vessel surveys of marine mammals in the Navarin Basin. One design was for surveys during the ice-free period from late spring to early fall. This design was modified for surveys during the late winter to early spring when sea ice is prevalent in the Basin. Because of the distinct differences between survey conditions and animal distributions during the ice-free and seasonal ice periods, two sampling approaches were necessary to accomplish the surveys.

ICE-FREE PERIOD - SPRING, SUMMER, AND FALL

The Basin was stratified into three survey zones (Figure 1). The shallow water zone coincided with the outer continental shelf, while the transition and deep water zones corresponded to the outer continental slope and rise, respectively. The former zone was the area northeast of a point 10 nm northeast of the 200 m contour line, and the latter zone was the area southwest of a point 10 nm southwest of the 3,000 m contour line. The area between these points was the transition zone, which featured the greatest topographic relief. The Basin was stratified in this manner to account for distributional differences of marine mammals relative to major changes in water depth. Moreover, areas of potential petroleum development in the Basin may be closely linked to the feasibility of extracting petroleum in various water depths.

Twenty-two sampling units were distributed over the three zones (Figure 1). The shallow water zone contained 11 units, the transition zone eight units, and the deep water zone three units. Each unit was approximately 34 nm by 72 nm and comprised about 2,450 nm^2. Nine transect lines, 30 nm long, were equidistantly spaced every 8 nm, corresponding to the longitude lines in each sampling unit (Figure 3). This configuration provided thorough coverage of a sampling unit and prevented double surveying of adjacent lines or units.

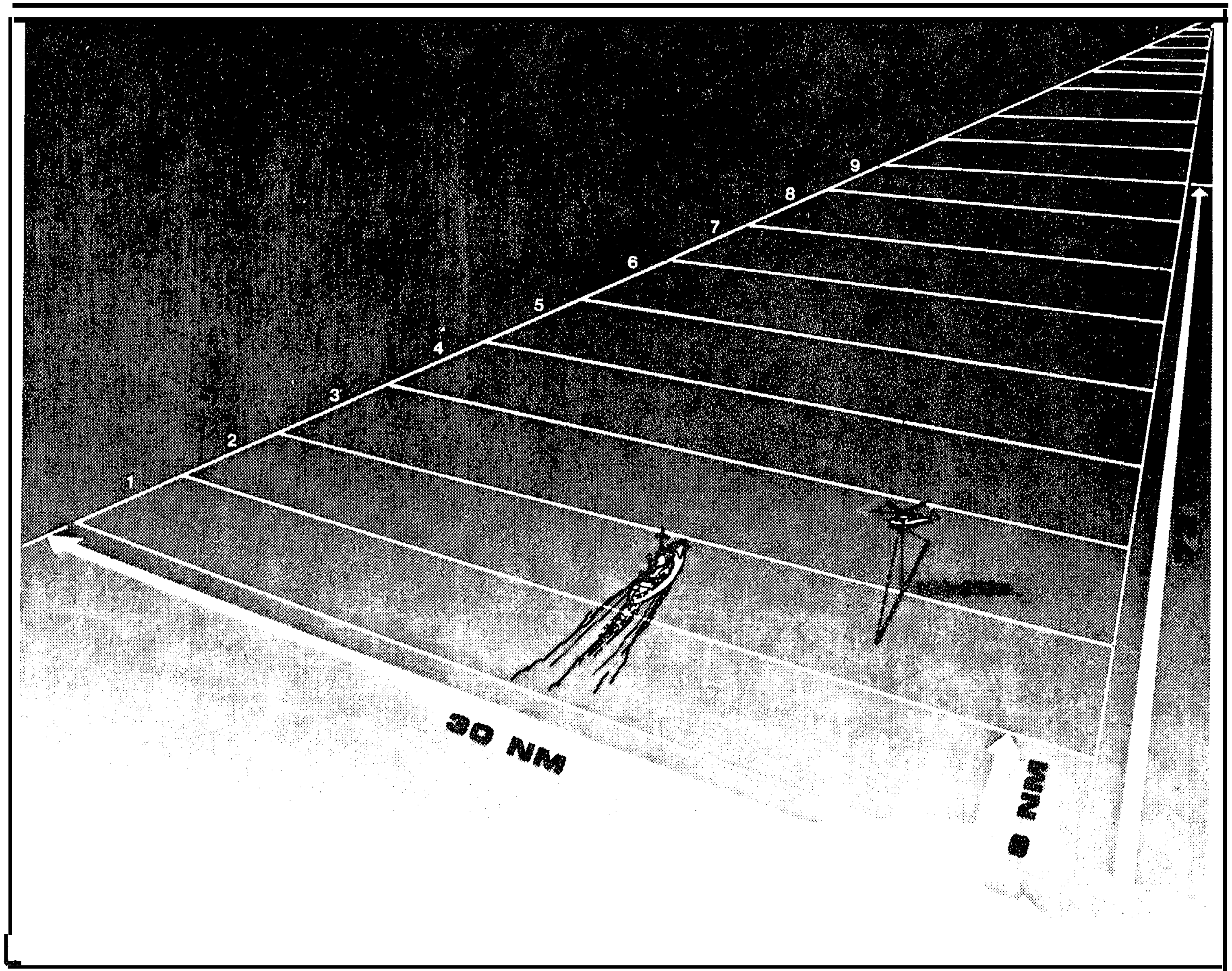

Figure 3 TRACKLINE ORIENTATION OF AERIAL AND VESSEL SURVEYS DURING SPRING THROUGH FALL PERIOD.

Aerial and vessel surveys were conducted along the transect lines of randomly selected sampling units (Figure 3). Survey effort in a given zone was allocated in proportion to the relative amount of area in each zone. Consequently, we attempted to allocate 50 percent of the survey effort in the shallow water zone, 36 percent in the transition zone, and 14 percent in the deep water zone.

Aerial surveys were conducted from a UH1M helicopter based on the NOAA ship SURVEYOR. Surveys were flown at altitudes of 150-230 m and at speeds of 65-75 kt. Two observers, one positioned in the co-pilot's seat and one in the right-aft section of the helicopter, provided data on marine mammals and environmental conditions to a data recorder; all data were recorded on computer-ready-forms. Data collected on marine mammals during a survey included number, species, vertical angle when an animal was perpendicular to the trackline, direction of travel, reaction to the aircraft, group size, time, and position. Environmental conditions including visibility (Appendix Table A-l), Beaufort Sea State Scale (Appendix Table A-2), sea surface temperature, and glare were evaluated at the start of each transect line surveyed, or whenever the conditions changed. Vertical angles were taken with clinometers and sea surface temperatures were obtained from a Barnes PRT-5. Positions were recorded from a GNS-500 every 3 nm along a transect line. The pilot was responsible for providing positions of the aircraft to the data recorder, maintaining a constant altitude and airspeed, and when possible, searching for marine mammals.

When the wind speed was greater than a Beaufort 4, the visibility less than 2 nm, or the ceiling below 150 m, vessel surveys were conducted along the transect lines in place of aerial surveys. Surveys were performed from the flying bridge, approximately 18.2 m above the water, and at a vessel speed of 12 kt. Two observers, individually stationed on the port and starboard sides of the vessel, recorded marine mammal and environmental data on the same variables described for the aerial surveys. Sea surface temperature, however, was obtained from bucket grab samples, and radial angles, instead of vertical angles, were taken with a sighting board or 10 minute surveyor's transit; animal distances from the vessel were estimated by observers who generally had substantial experience with this estimation procedure. Water depth was recorded every 3 nm. Vessel surveys were terminated when wind speed exceeded a Beaufort 6.

Vessel surveys were also conducted in conjunction with the aerial surveys (Figure 3). The ship travelled an east-west route along the mid-latitudinal points of the north-south transect lines. One observer, positioned on the flying bridge, recorded marine mammals encountered along the trackline. The use of the ship during the aerial surveys was for the purpose of collecting distributional information on marine mammals, providing safeguards to the helicopter crew, and permitting efficient refueling of the helicopter during the aerial surveys.

SEASONAL ICE PERIOD - WINTER

During the seasonal ice period, the Basin was stratified into three zones identified as the open water, marginal ice front, and heavy pack ice zones. The former zone occurred entirely in open water, while the heavy pack ice zone was primarily in areas of 90 to 100 percent ice coverage; the marginal ice zone was intermediate to these two strata and consisted chiefly of 10 to 90 percent ice coverage. The size of each zone varied according to the movement of the sea ice during the course of the study. Although this stratification procedure was developed, the open water zone was not surveyed because of persistent high seas, nor was the heavy pack ice surveyed since the ice-breaker had difficulty penetrating the dense, and at times thick, pack ice. Consequently, the entire survey effort was devoted to the marginal ice zone, where the largest number and greatest diversity of marine mammals were expected to be found (Burns et al. 198(I, Brueggeman 1982).

Six sampling units were equidistantly distributed across the marginal ice front between longitudes 171°12'W and 179°36'W {Figure 4). Although each unit was 36 nm wide, the north and south boundaries varied since they corresponded to the edge of the ice and the start of heavy pack ice; boundaries that are governed by wind and currents. The average sampling unit size was 2,730 nm^2, with a range of 1,474 to 3,731 nm^2.

Aerial and vessel surveys were conducted along seven paired transect lines established in each sampling unit (Figure 5). The paired transect lines were spaced every 4 nm and corresponded to the longitude lines. Individual transect lines comprising each pair were separated by 2 nm and extended 30 nm from the interface of the marginal ice front with the open water into the pack ice; the exact length of the transect lines varied depending on ice conditions and a combination of logistical factors influencing opportunities for surveys.

Aerial surveys were conducted from two Sikorsky H-52-A helicopters based on the U.S. Coast Guard icebreaker POLAR SEA (Figure 5). The helicopters flew parallel to each other or singly along the transect lines at speeds of 65-75 kt and at altitudes of 150-230 m. Observer and data collection procedures were the same as followed for aerial surveys during the ice-free period. The only difference was that navigation was determined from Loran-C systems on each helicopter, and ice thickness, size, and concentration were evaluated every 3 nm along the transect line by the observer occupying the co-pilot’s seat in each helicopter; ice characteristics were evaluated by the same two observers for every survey to maintain data consistency (Appendix Table A-3 defines ice characteristics). Single helicopter surveys were flown along the transect lines when one helicopter was inoperable. Under these circumstances, the Coast Guard restricted the range of the helicopter to 8 nm from the ship. To maximize the use ofa single . . helicopter, the ship travelled a predetermined course, while the

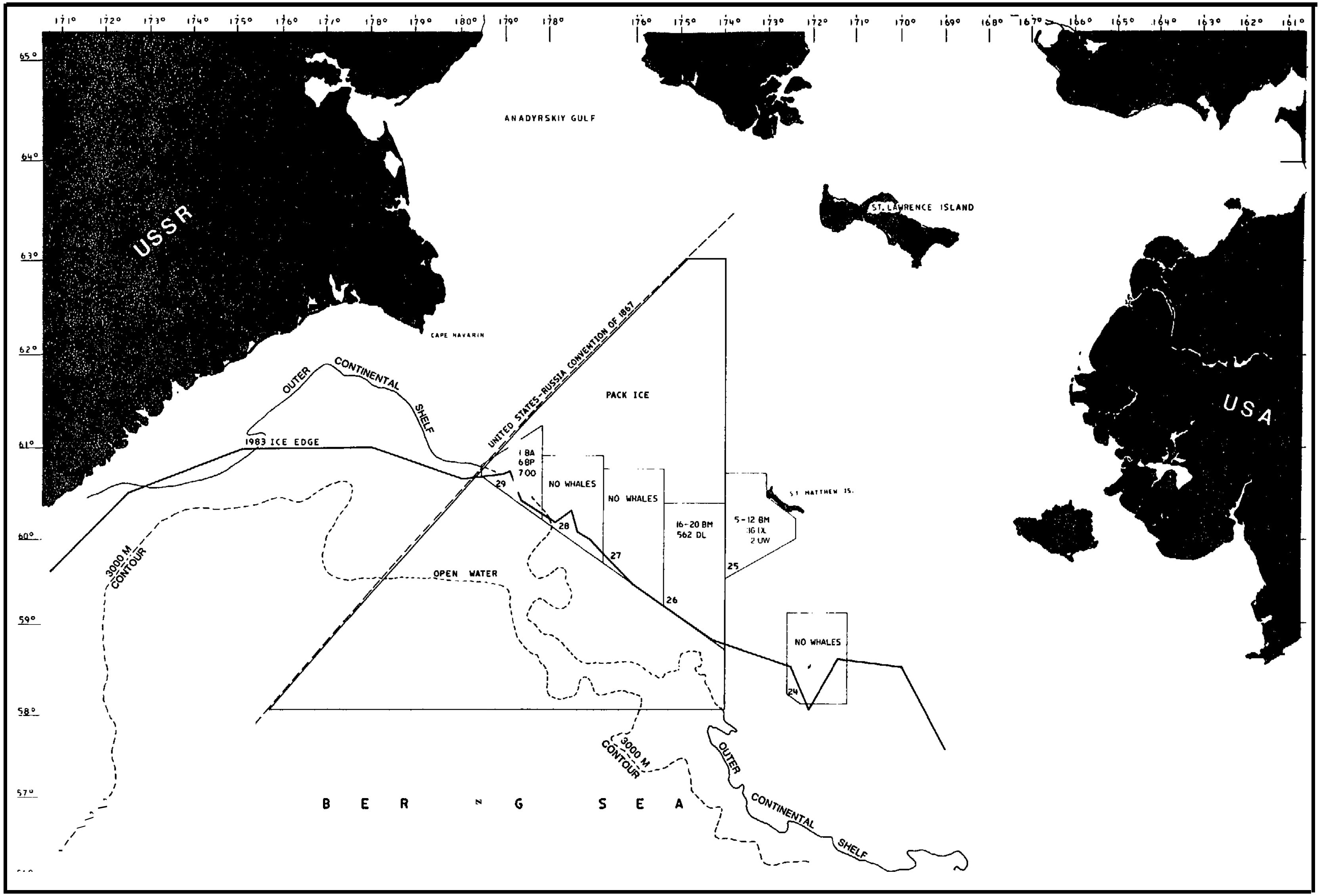

FIGURE 4 SAMPLING DESIGN AND DISTRIBUTION OF WHALES IN THE SIX SAMPLING UNITS SURVEYED IN THE VICINITY OF THE NAVARIN BASIN DURING WINTER , 19 FEBRUARY – 18 MARCH, 1983 (SEE FIGURES 7 AND 8 AND TABLE 5 IN APPENDIX A FOR LOCATIONS OF SURVEY TRACKLINES AND ANIMALS).

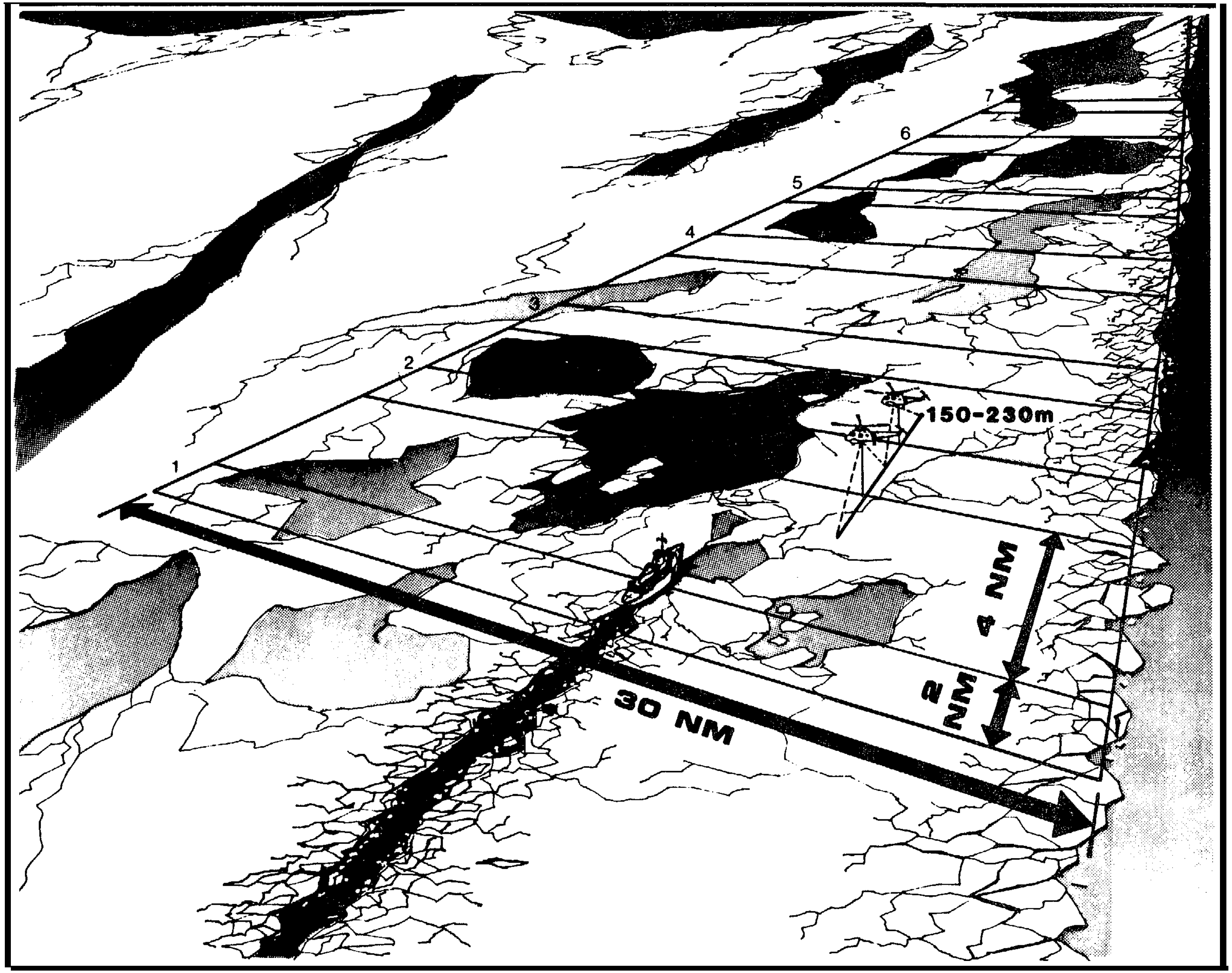

FIGURE 5 TRACKLINE ORIENTATION OF **AERIAL** AND VESSEL SURVEYS **DURING WINTER.**

TABLE 2

TEST OF UNIFORMITY OF WHALE OBSERVATIONS RECORDED UNDER VARIOUS VISIBILITY CONDITIONS DURING THE SPRING THROUGH FALL AERIAL AND VESSEL SURVEYS

	Aerial surveys b/			Vessel surveys c/			
Visibility a/ condition	Distance surveyed (rim)	Observed number	Expected number d/	Distance surveyed (rim)	Observed number	Expected number	X^2 value
Fair	805	4	3	1153	7	13	2.86
Good-excellent	6898	25	26	1657	25	19	.99
Total	7703	29	29	2810	32	32	4.85 e/

a/ Unacceptable and poor conditions were excluded from analysis because of small numbers of whale observations. Good to excellent conditions were pooled to increase sample sizes.

b/ Large whales (fin, gray, and minke pooled) were included in the analysis, while too few sightings were recorded for killer whales to analyze. All whales were assumed to be equally visible during fair to excellent conditions.

c/ Only Dan's propoises were included in this analysis, since the number of other whales were insufficient for analysis. All other whales were assumed to be equally visible under good to excellent conditions.

d/ Expected values were not statistically testable since more than 20 percent of those values were less than 5.

e/ Statistically significant at the 0.05 level.

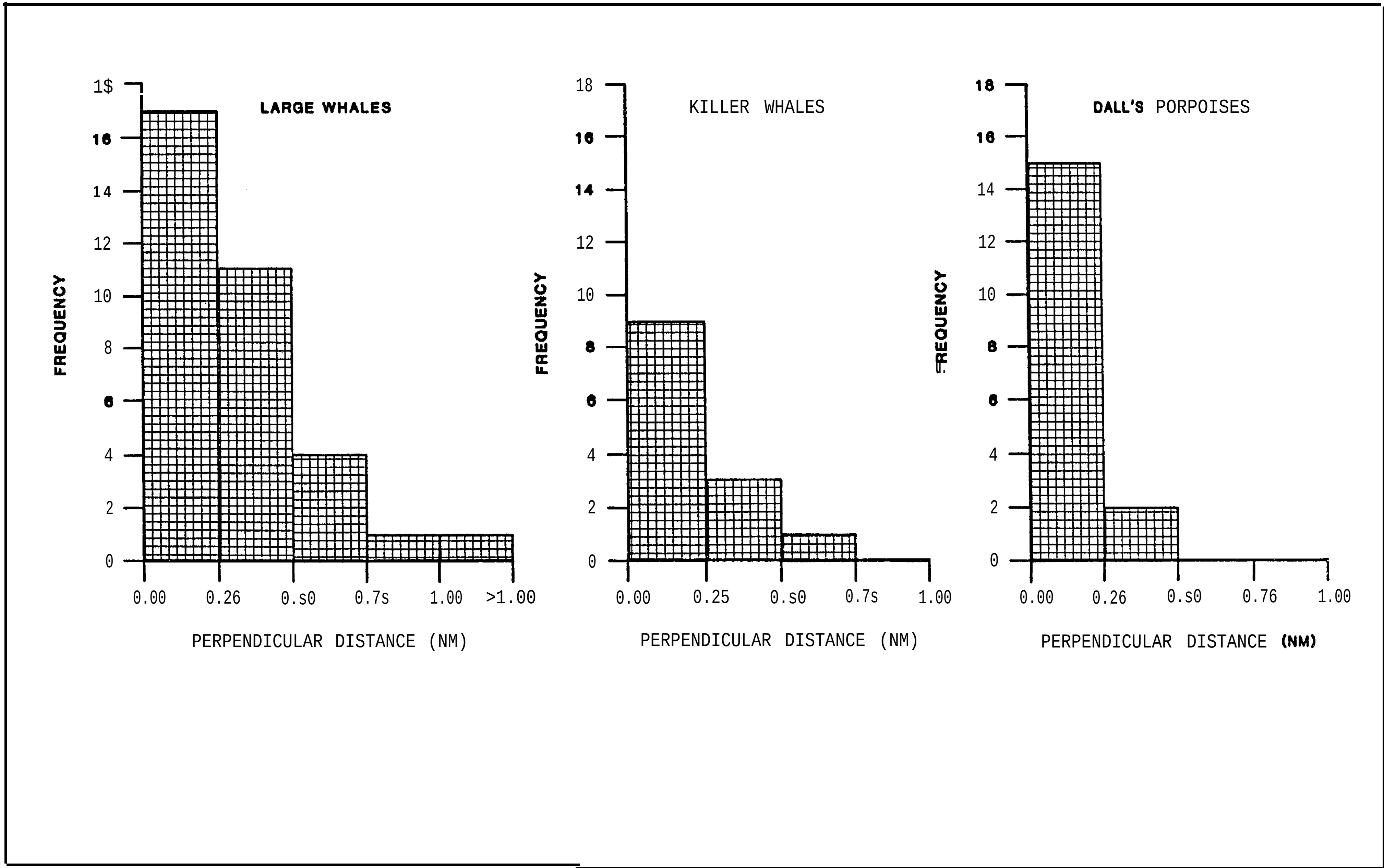

Figure 6 FREQUENCY DISTRIBUTION OF PERPENDICULAR DISTANCES OF LARGE (fin, gray, **minke,**) AND KILLER WHALES SIGHTED DURING AERIAL SURVEYS AND **DALL'S** PORPOISES SIGHTED DURING VESSEL SURVEYS.

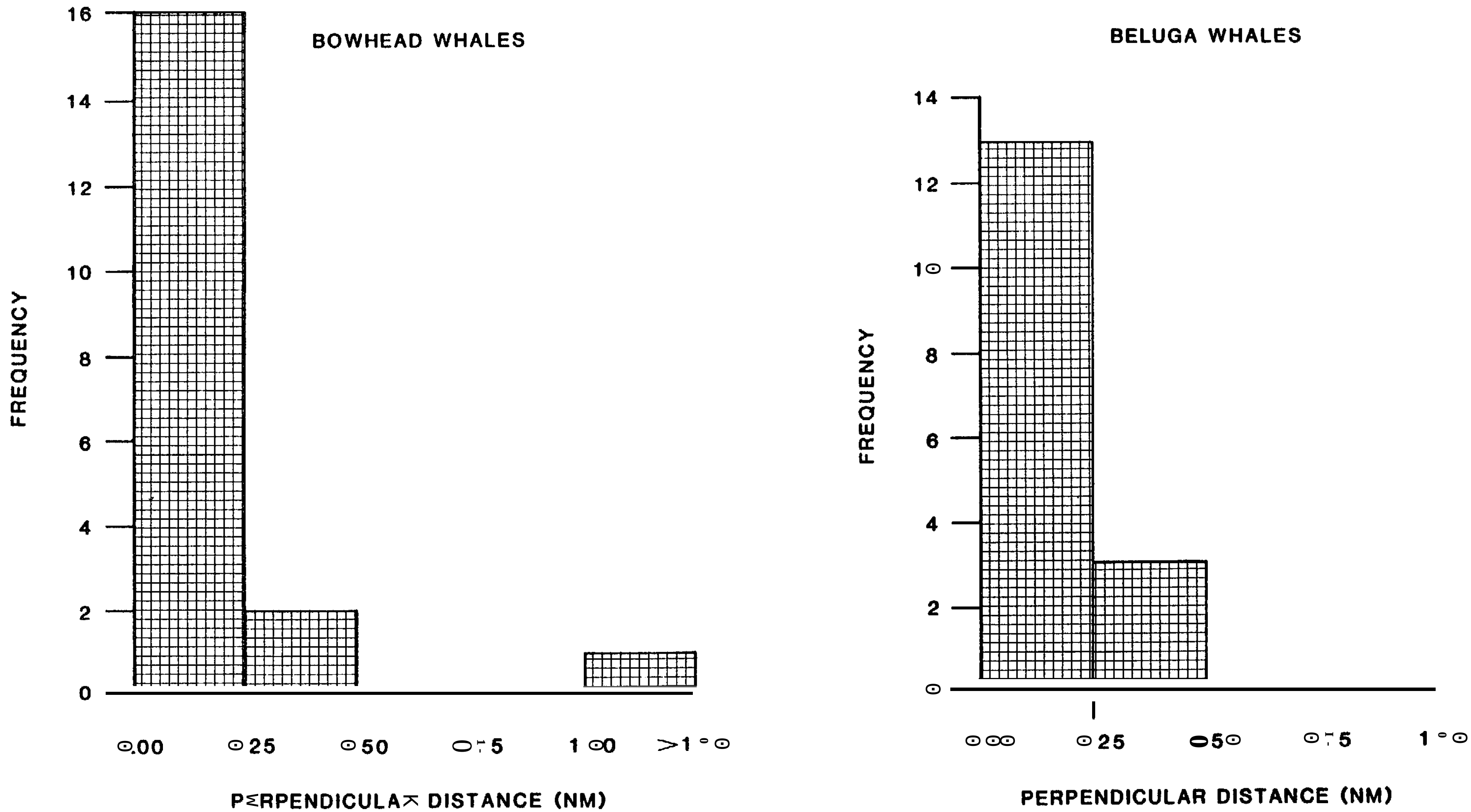

Figure 7 FREQUENCY DISTRIBUTION OF PERPENDICULAR DISTANCES OF BOWHEAD AND BELUGA WHALES SIGHTED DURING AERIAL SURVEYS.

Estimates of the density and abundance of whales and associated variances were calculated from methods developed by Estes and Gilbert (1978) for strip-transect analysis. Density and abundance were calculated by summing the sampling unit estimates for each zone and then summing the zone estimates for the **Navarin** Basin.

The estimator has the following form:

Estimated density is:

$$D_i = \Sigma y_i / \Sigma x_i$$

where D_i = the density of whales per nm^2 for a zone
y_i = the number of whales in the i^{th} transect strip, and
x_i = the area of the i^{th} transect strip

Estimated variance of D_i is:

$$S^2_{D_i} = [\Sigma (y_i^2 / x_i) - D \Sigma y_i] / (n-1)(\Sigma x_i)$$

where n = the number of transects surveyed.

Estimated abundance for a zone is:

$$T_i = D_i A_i$$

where: T_i = abundance of whales in a zone, and
A_i = total area of that zone

Estimated abundance for all zones is

$$T = \Sigma T_i$$

Estimated variance of T is:

$$V(T) = A (A - \Sigma x_i) S^2_{D_i}$$

The 95 percent confidence interval for T is:

$$T + 1.96 \sqrt{V(T)}$$

Other statistical procedures used in the analysis were Chi-square goodness of fit for testing habitat utilization by whales and ANOVA for comparing group sizes of whales and testing habitat characteristics. All tests were performed at the 0.05 level of significance.

RESULTS

A total of 147 to 158 observations of 968 to 979 whales, representing eight species, were recorded in the Navarin Basin during four seasonal surveys between 11 May 1982 and 18 March 1983 (Table 3). Four endangered species of whales--fin, gray, bowhead, and right--were recorded during the aerial and vessel surveys. These species comprised over 31 percent of the total observations and 12 percent of the individuals. Fin whales were most abundant, followed by gray, bowhead, and right whales. Other species encountered in the Basin were minke, beluga, killer whales and Dan's porpoises. These species represented over 62 percent of the whale observations and 86 percent of the individual animals. Belugas were most abundant followed by Dan's porpoises, killer whales, and minke whales. Fin, minke, and killer whales were observed in the Basin every season, while Dalls' porpoises were recorded during the three ice-free seasons and beluga and bowhead whales during the winter. Right whales were observed only during the summer and gray whales only during the fall. There were also 3 observations of 5 unidentified baleen whales. Over83 percent of all whales recorded were observed from helicopters, which travelled 68 percent of the 8,136 nm surveyed in the 54,078 nm^2 Navarin Basin. No calves were encountered in the Basin.

SPRING SURVEY PERIOD

Four species and 129 individual whales were observed during 2,482 nm of aerial and vessel surveys in the Basin (Table 4). The Dall's porpoise was the most commonly encountered species, followed by the killer, fin, and minke whales. Fin and killer whales were chiefly recorded during aerial surveys, while minke whales and Dan's porpoises were observed primarily from the vessel. Aerial surveys accounted for approximately 74 percentof the 2,135 nm of systematic trackline censured; an . additional 347 nm of opportunistic vessel surveys were covered in the Basin.

TABLE 3

NUMBER OF OBSERVATIONS AND INDIVIDUALS OF WHALES RECORDED DURING THE FOUR SEASONAL SURVEYS OF THE NAVARIN BASIN, 11 MAY-10 JUNE, 20 JULY-19 AUGUST, 29 OCTOBER-12 NOVEMBER 1982, ANO 19 FEBRUARY-18 MARCH 1983

Species	Spring				Sumner				Fall				Winter				Total			
		No. Individuals				No. Individuals				No. Individuals				No. Individuals				No. Individuals		
	No. obs.	Vessel	Aerial	Total	No. obs.	Vessel	Aerial	Total	No. obs.	Vessel	Aerial	Total	No. obs.	Vessel	Aerial	Total	No. obs.	Vessel	Aerial	Total
Fin whale	11	- a/	26	26	3		6	6	5	-	13	13	1	6	-	6	20	6	45	51
Right whale					1	2		2		-							1	2	-	2
Gray whale									18	-	44	44					18		44	44
Bowhead whale										-			7-18	1	20-31	21-32	7-18	1	20-31	21-32
Minke whale	3	3		3	1	1		1	3	-	3	3	1	1	-	1	8	5	3	8
Killer whale	10	1	34	35	2	2	3	5	3	-	17	17	1	7	-	7	16	10	54	64
Beluga whale										-			29		598	598	29		598	598
Dan's porpoise	17	61	4	65	18	37	17	54	10	34	22	56					45	132	43	175
Unidentified whale	—	—	—	—	—	—	—		2	3	—	3	1	—	2	2	3	3	2	5
TOTAL	41	65	64	129	25	42	26	68	41	37	99	136	40-51	15	620-631	635-646	147-158	159	809-820	968-979

a/ Dash (-) signifies no animals were observed.

TABLE 4

NUMBER OF WALES OBSERVED DURING THE SPRING AERIAL AND VESSEL SURVEYS
OF THE NAVARIN BASIN, 11 MAY - 10 JUNE 1982

Zone	Sampling unit	Trackline distance surveyed[a/] Aerial (%)	Vessel (%)	Total (nm)	Fin whale No. obs	Fin whale No. indiv	Minke whale No. obs	Minke whale No. indiv	Killer whale No. obs	Killer whale No. indiv	Dan's porpoise No. obs	Dan's porpoise No. indiv	Total No. obs	Total No. indiv
Shallow water	5	53	47	210 [23][b/]		[c/]	-	-		-	-			-
	8	30	70	298 [21]			2	2		-	3	8	5	10
	10	100	0	270 [71]	11	26	-	-		-	1	2	12	28
	11	100	0	270 [33]		.	-	-	10	35	1	2	11	37
Subtotal		71	29	1048 [148]	11	26	2	2	10	35	5	12	28	75
Transition	7	100	0	270 [63]			-	-		-	1	2	1	2
	21	100	0	270 [64]			-	-		-	-	-		-
	22	6	94	277 [0]			-	-		-	5	14	5	14
Subtotal		68	32	817 [127]			-	-		-	6	16	6	16
Deep water	20	100	0	270 [73]			1	1		-	6	37	7	38
Subtotal		100	0	270 [73]			1	1		-	6	37	7	38
TOTAL		74	26	2135 [347]	11	26	3	3	10	35	17	65	41	129

a/ Total trackline length available in each sampling unit was 270 nm.

b/ Brackets [ ] include nautical miles surveyed by the vessel during aerial surveys; incidental marine mammal sightings were recorded for determining species distribution in the Basin.

c/ Oash (-) signifies no animals were observed.

Eight sampling units were surveyed in the Basin (Table 4). Four of these eight were in the shallow water zone, three in the transition zone, and one in the deep water zone. Correspondingly, approximately 49 percent of the survey effort was in the former zone, 13 percent in the latter zone, and 38 percent in the transition zone. Aerial surveys predominated the survey effort in each zone, although units 8 and 22 were primarily censused by vessel because of weather conditions. Virtually the entire 270 nm of trackline available in each of the eight sampling units was censused. Surveys in the northern third of the Basin (units 1 through 4) were precluded by sea ice which was too extensive for the vessel to penetrate.

Sea state and visibility conditions during the surveys were usually sufficient to accurately census whales during 13 of the 30 day spring field season (Table 5). Visibility was good to excellent during 80 percent of the survey time that included less than 50 percent glare. Wind speed averaged 11 kt and sea state was below Beaufort4, 65 percent of the survey time. Survey conditions were marginal only in sampling, unit 22 of the transition zone where Beaufort 5 sea state and fair visibility predominated. Additional surveys were precluded by bad weather, piggyback scientific operations, transit time to and from the Basin, and ancillary ship activities that accounted for 17 of the 30 field days (Appendix Table A-4).

Whales were observed in all three zones of the Navarin Basin (Figure 8). Animal counts were highest in the shallow water zone of the outer continental shelf and lowest in the transition zone. Species diversity was also greatest on the shelf. Fin and killer whales were observed only in the shelf waters, while Dan's porpoises occurred in all three zones, particularly the deep water zone. Fin whales were in sampling unit 10 at a water depth of 130 m, killer whales in unit 11 at a depth of 100 m, and DalI's porpoises in 6 of the 8 units at depths ranging from 126 m to over 3,700 m. Minke whales were observed in both the shallow and deep water zones in depths similar to those for Dan's porpoises. No whales were observed in units 5 and 21.

TABLE 5
VISIBILITY AND SEA STATE CONDITIONS DURING SPRING AERIAL AND VESSEL SURVEYS OF MARINE MAMMALS IN THE NAVARIN BASIN, 11 MAY - 10 JUNE 1982

Zone	Sampling unit	Beaufort wind scale (%) 0	1	2	3	4	5	Visibility conditions (%)[a/] UN	0		GO	G	EX	Total distance surveyed (rim)
Shallow water	5	-	-	-	73	27	-	-[b/]	4	31	44	21	-	210
	8		9	2	87	2	-	2	-	14	23	58	3	298[c/]
	10	-	-	-	56	44	-	-	-	-	72	28	-	270
	11	-	42	47	11	-	-	-	-	-	-	58	42	270
Subtotal		-	13	13	57	17	-	T[d/]	T	10	34	43	12	1048
Transition	7		-	11	89	-	-		1	6	58	35	-	270
	21	-	-	-	-	100	-			15	79	6	-	270
	22	-	-	-	-	41	59		-	93	7	-	-	277
Subtotal		-	-	4	29	47	20		T	38	48	14	-	817
Deep water	20	-	-	56	40	4	-	-	-	6	19	75	-	270
Subtotal	20		-	56	40	4	-	-	-	6	19	75	-	270
TOTAL			6	15	44	27	8	T	T	20	38	36	6	2135

a/ UN = unacceptable, PO = poor, FA = fair, GO = good, VG = very good, and EX = excellent as defined by NODC.
b/ Dash (-) signifies that a visibility condition did not occur.
c/ Trackline distance exceeded 270 nm because vessel course varied about the line.
d/ T signifies percentage less than 0.5.

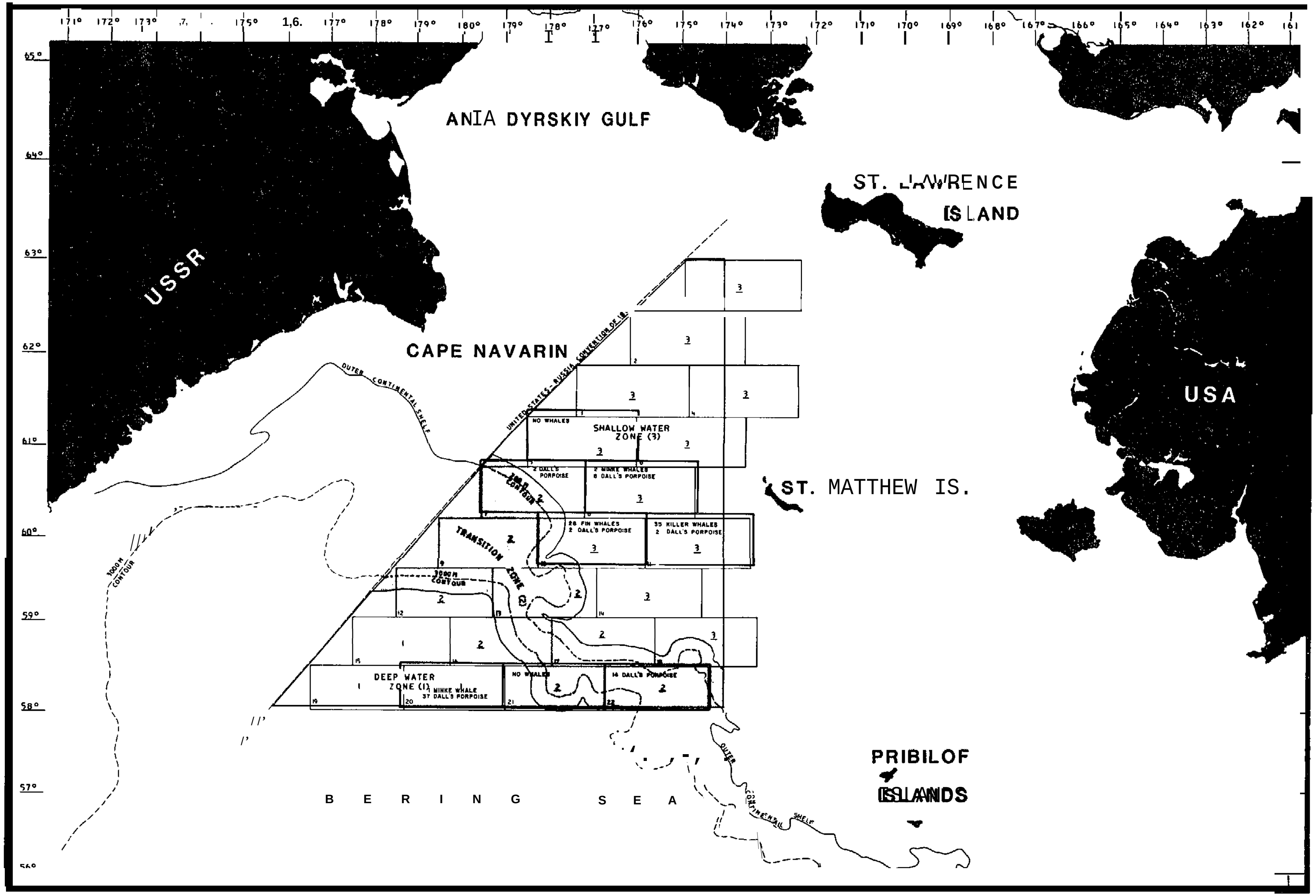

FIGURE 8 DISTRIBUTION OF WHALES IN THE EIGHT SAMPLING UNITS SURVEYED IN THE NAVARIN BASIN DURING SPRING, 11 MAY - 10 JUNE, 1982 (SEE FIGURES 1 AND 2 AND TABLE 5 IN APPENDIX A FOR SPECIFIC LOCATIONS OF SURVEY TRACK LINES AND ANIMALS).

Movements of whales in the Basin were variable during spring (Figure 9). Fin and minke whales were observed moving in a northerly to westerly direction in groups averaging 2.1 (n=11) and 1 (n=1) animals, respectively. Fin whales appeared to be feeding while traveling, since large concentrations of birds and water discoloration were associated with the whales (Harrison 1979). Killer whales also seemed to be primarily traveling in northerly to westerly directions, but along the fringe (Burns etal. 1980) of the pack ice in groups averaging 3.5 (n=10) animals where pinnipeds were prevalent. There was no consistent direction of movement for Dan's porpoises, which had an average group size of 3.8 (n=21) animals. Since the Dan's porpoises and minke whales were primarly encountered during vessel surveys, their movement patterns may have been influenced by the vessel. The other species did not appear to be disturbed by the survey platforms.

An estimated 670 fin, minke, and killer whales or 16 animals per 1,000 nm^2 were in the Basin during spring (Table 6). This estimate was based on observations of 49 animals along 1,769 nm of systematic trackline, representing approximately 4 percent coverage of the Basin. Killer whales were most abundant andminke whales least abundant. Fin whales, the only endangered species encountered, had an estimated abundance of 259 animals or 6 animals per 1,000 nm^2. All whales occurring within the boundaries of the survey strip were solely in the shallow water zone, although coverage in the transition and deep water zones was 2.8 percent and 3.7 percent, respectively, compared to 6.3 percent in the shallow water zone. Dan's porpoise abundance was not estimated because too little area was surveyed under acceptable viewing conditions to provide a meaningful value. The confidence limits around the abundance estimates for the other species were wide because of the small sample sizes. Moreover, these estimates do not account for animals below the surface or otherwise missed during a survey. Consequently, the actual abundance was probably higher, particularly since replicate counts of several whale pods exceeded twice the number of animals initially recorded.

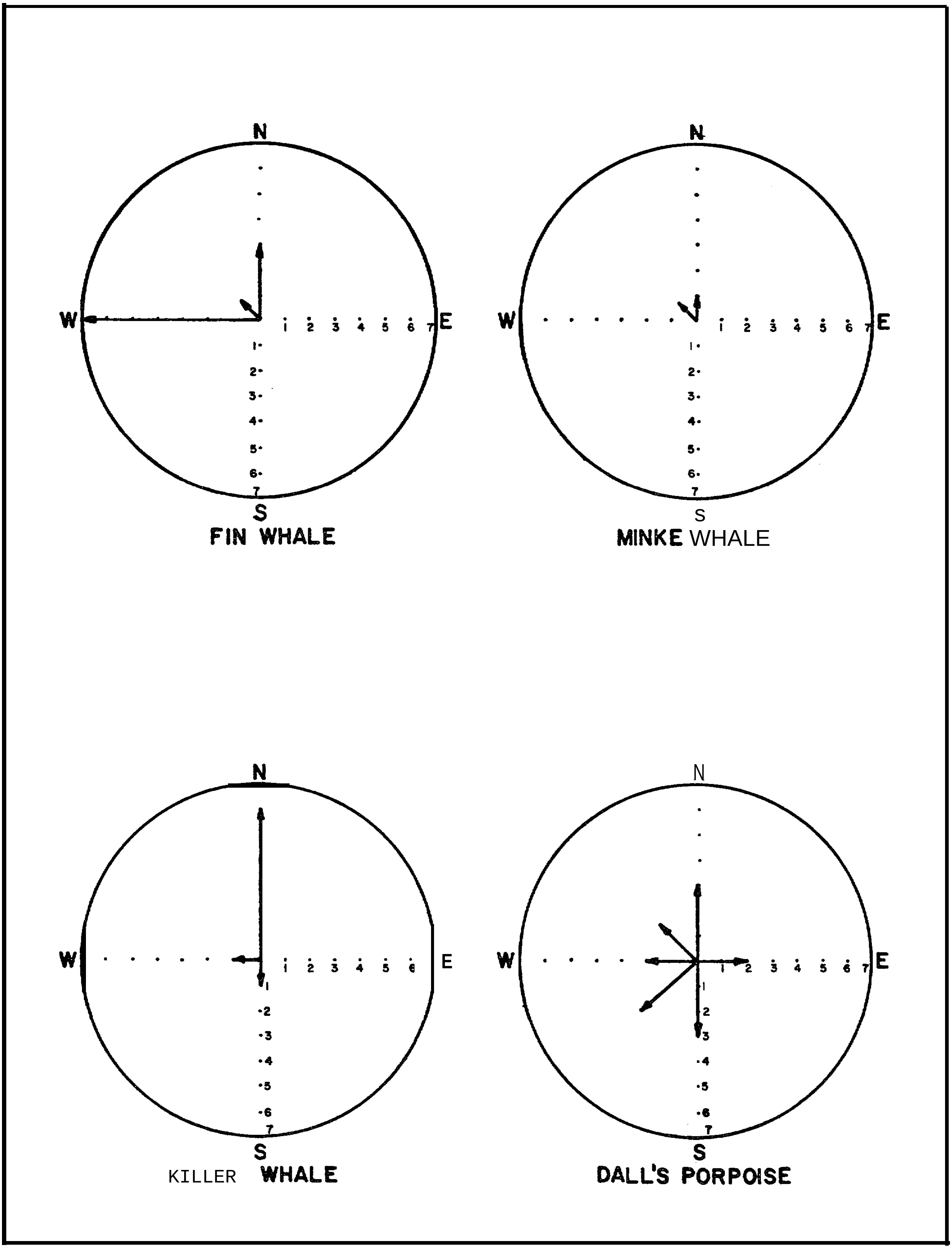

Figure 9 **FREQUENCY OF WHALES OBSERVED POINTED** IN A GIVEN **DIR ECTION** OF TRAVEL IN THE **NAVARIN** BASIN **DURING** SPRING, MAY - JUNE **1982.**

TABLE 6

ESTIMATED ABUNDANCE OF WHALES IN THE NAVARIN BASIN DURING SPRING

Zone	Sampling unit	Total area (nm^2)	% area coverage: Aerial	Vessel	Total	Fin whale: Obs. No. a/	Est. No.	Minke whale: Obs. No.	Est. No.	Killer whale: Obs. No.	Est. No.	Total: Obs. No.	Est. No.
Shallow water	5	2458	4.5	1.3	5.8	- b/		-	-			-	
	8	2452	3.7	6.5	10.2			1	10			1	10
	10	2461	11.0	0	11.0	19	173		-		-	19	173
	11	2461	11.0	0	11.0			-	-	29	264	29	264
Subtotal		9832	% 3	2.0	9.5	19	173	1	10	29	264	49	447
All units		14,740	5.0	1.3	6.3		259		15		396		670
Transition	7	2452	11.0	0	11.0								
	21	2461	11.0	0	11.0								
	22	2461	0.7	0.4	1.1								
Subtotal		7374	7.6	0.1	7.7								
All units		19,651	2.8	T	2.8								
Deep water	20	2461	11.0	0	11.0								
Subtotal		2461	11.0	0	11.0								
All units		7379	3.7	o	3.7								
TOTAL		41,770	3.8	0.5	4.3	19	259 ± 559 c/	1	15 ± 40	29	396 ± 713	49	670

a/ Number of whales recorded in. survey strip.
b/ Dash (-) signifies no animals.
c/ Ninety-five percent confidence limits.

SUMMER SURVEY PERIOD

Sixty-eight whales comprising five species were recorded during 1,590 nm of aerial and vessel surveys in the Basin (Table 7). Dan's porpoises represented almost 80 percent of the total observations, while six or fewer fin, killer, right, and minke whales were recorded. The majority of the fin and killer whales were observed during aerial surveys, whereas most animals of the other three species were counted from the vessel. Aerial surveys accounted for 71 percent of the 1,385 nm of systematic trackline examined; the remaining 402 nm of Systematic and 205 nm of opportunistic trackline were censused by vessel.

Eight sampling units were surveyed in the Basin during summer (Table 7). Five units were censused in the shallow water zone, two in the transition zone, and one in the deep water zone. Survey effort in these zones was 66 percent in the former zone, 14 percent in the latter zone, and 20 percent in the transition zone of the total 1,386 nm censused. Helicopter surveys predominated in each zone except for the transition zone, which was primarily censused by vessel. The vessel was predominantly used in sampling units 22 and 11 where weather conditions limited use of the helicopter. There was no sea ice in the Basin during the summer period to cause access problems similar to those reported in the spring.

Sea state and visibility conditions were largely acceptable for censusing whales during 10 of the 31 day summer field season (Table 8). Visibility was good to excellent approximately 75 percent of the survey time and sea state was below Beaufort 5, 91 percent of the time; under these environmental conditions glare was less than 50 percent and wind speed averaged 14 kt. Survey conditions were marginal for over half the distance surveyed in sampling units 11, 20, and 22. Additional surveys were not conducted during the remaining 21 of the 31 day summer field period because of bad weather, piggyback scientific operations, transiting to and from the study area, and ancillary ship activities (Appendix Table A-4).

TABLE 7
NUMBER OF WHALES OBSERVED DURING THE SUMMER AERIAL AND VESSEL SURVEYS
OF THE NAVARIN BASIN, 20 JULY - 19 AUGUST 1982

Zone	Sampling unit	Trackline distance surveyed[a/] Aerial	Vessel	Total (nm)	Fin whale No. obs	Fin whale No. indiv	Right whale No. obs	Right whale No. indiv	Minke whale No. obs	Minke whale No. indiv	Killer whale No. obs	Killer whale No. indiv	Dall's porpoise No. obs	Dall's porpoise No. indiv	Total No. obs	Total No. indiv
Shallow water	1	94	6	255 [50][b/]	-[c/]										-	
	5	100	0	270 [63]	3	6			1	1	1	3	12	38	17	48
	6	64	36	210 [24]	-		1	2							1	2
	8	100	0	75 [18]							-	-			-	-
	11	18	82	101 [6]	-		-	-	-	-	1	2	2	5	3	7
Subtotal		81	19	911 [161]	3	6	1	2	1	1	2	5	14	43	21	57
Transition	9	81	19	129 [18]			-	-					2	5	2	5
	22	0	100	150 [0]			-	-	-	-	-	-	2	6	2	6
Subtotal		38	62	279 [18]									4	11	4	11
Deep water	20	69	31	195 [26]			-	-	-	-						
Subtotal		69	31	195 [26]												
TOTAL		71	29	1385 [205]	3	6	1	2	1	1	2	5	18	54	25	68

a/ Total trackline length available in each sampling unit was 270 nm.

b/ Brackets [ ] include nautical miles surveyed by the vessel during aerial surveys; incidental marine mammal sightings were recorded for. determining species distribution in the Basin.

c/ Oash (-) signifies no animals were observed.

TABLE 8

VISIBILITY AND SEA STATE CONDITIONS DURING SUMMER AERIAL AND VESSEL SURVEYS
OF MARINE MAMMALS IN THE NAVARIN BASIN, 20 JULY - 19 AUGUST 1982

Zone	Sampling unit	Beaufort wind scale (%)							Visibility conditions (%)a/						Tots 1 distance surveyed (rim)
							5		UN	Po				EX	
Shallow water	l	-	-	-	73	27	-	-	b/	-	4	72	24		255
	5	-	-	56	44	-	-	-	6	-	-	-	94		270
	6	-	-	-	64	21	15	-	-	1	7	43	34	15	210
	8	-	-	-	100	-	-	-	-	-	-	-	100		75
	11	-	-	15	39	46	-	-	6	8	54	27	5		101
Subtotal			-	18	61	17	4	-	2	1	9	33	51	4	911
Transition	9	-	-	-	54	23	23	-	3	15	12	70			129
	22	-	-	-	40	40	20	-	-	25	49	26			150
Subtotal		-	-	-	46	32	22	-	1	21	32	46			279
Deep water	20	-	-	-	-	80	20	-	-	1	51	48			195
Subtotal		-	-	-	-	80	20	-	-	1	51	48			195
TOTAL			-	12	50	29	9		2	5	19	38	34	2	1385

a/ UN = unacceptable, PO = poor, FA = fair, GO = good, VG = very good, and EX = excellent as defined in Appendix Table 1.

b/ Dash (-) signifies that a visibility condition did not occur.

Whales were observed in 2 of the 3 zones during the summer (Figure 10). The majority of whales were recorded in the shallow waters of the outer continental shelf where the species diversity was also highest. Fin, right, minke, and killer whales were exclusively encountered in the shelf waters. Right whales were observed in unit 6 at a water depth of 104 m, while fin, minke, and killer whales all occurred in sampling unit 5 at depths ranging from 110 to 120 m; killer whales also were in unit 11. Dan's porpoises were more widespread than the other species since they occurred in 4 units distributed in the shallow water and transition zones where depths ranged from 110 m to over 1,000 m. No whales were observed in sampling units 1, 8, or the deep water zone.

Summer movement patterns of whales in the Basin were unclear (Figure 11). Directions of movement of fin whales and Dan's porpoises were quite variable, possibly suggesting these species were feeding in the Basin. Fins travelled in average group sizes of 2.0 (n=4) and DalI's porpoises in groups of 2.8 (n=13) animals. Too few observations were recorded for the other species to suggest any definite movement patterns; one group of 2 right whales and 2 groups of 5 killer whales were recorded. The movements of the animals did not appear to be influenced by the survey platforms, except for Dall's porpoises and minke whales, which may have been attracted to the vessel.

During the summer period, 183 whales at a density of 3 animals per 1,000 nm2 were estimated in the Basin (Table 9). This estimate was based on observations of 8 whales along 1,085 nm of strip transect representing 2 percent coverage of the Basin. Densities were highest for fin whales and lowest for killer whales; right whales were intermediate in abundance. Abundance estimates for these species were 84 fin whales or 2 animals per 1,000 nm^2, compared to 57 right whales and 42 killer whales at densities of 1.1 and 0.8 animals per 1,000 nm^2, respectively. All animals recorded in the designated strip boundaries were in the shallow water zone where survey coverage was 2.9 percent; coverage in the deep water zone was 1.8 percent and 0.7 percent

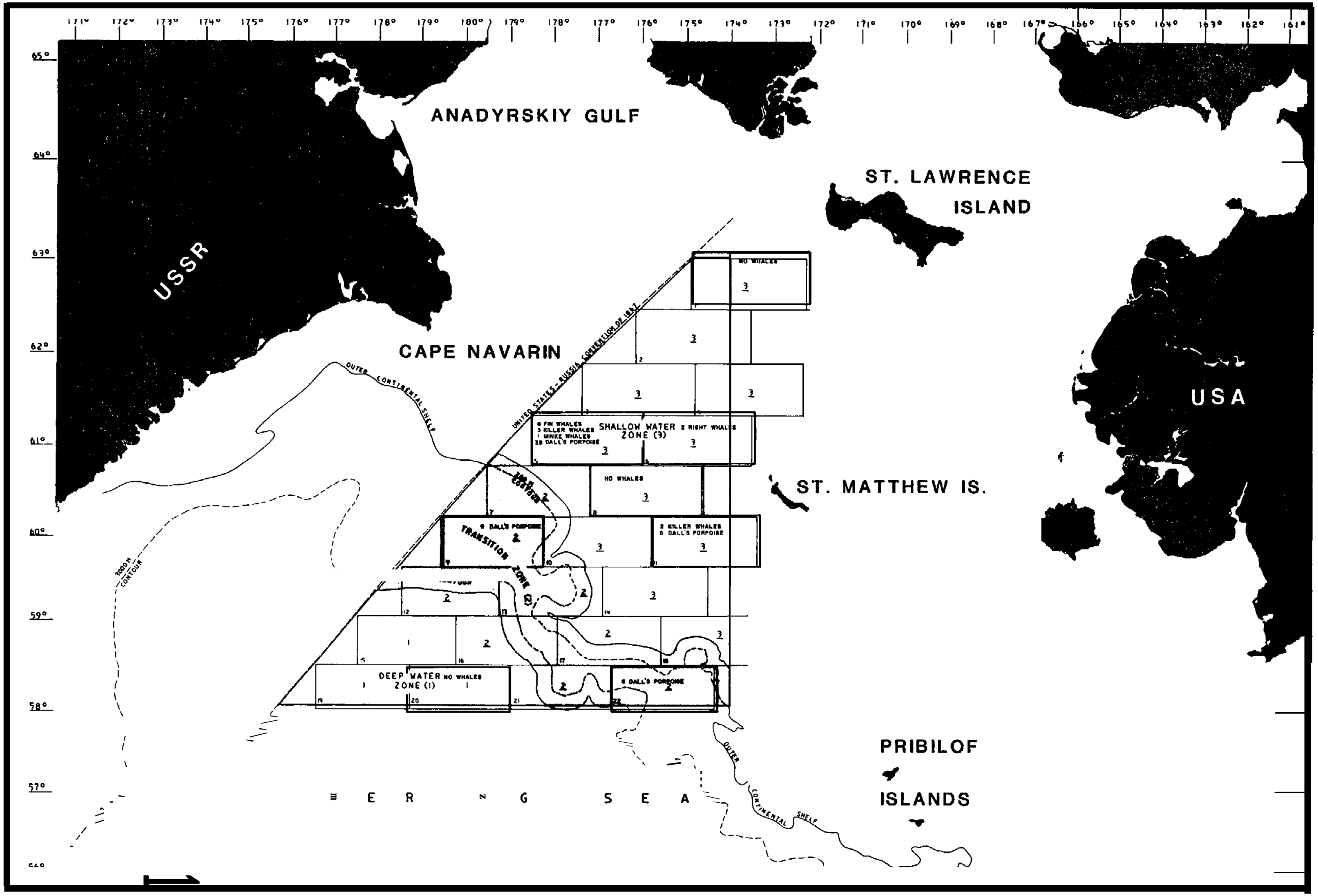

FIGURE 0 DISTRIBUTION OF WHALES IN THE EIGHT SAMPLING UNITS SURVEYED IN THE NAVARIN BASIN DURING SUMMER, JULY 20 - AUGUST 19, 1982 (SEE FIGURES 3 AND 4 AND TABLE 5 APPENDIX A FOR LOCATIONS OF SURVEY TRACKLINES AND ANIMALS).

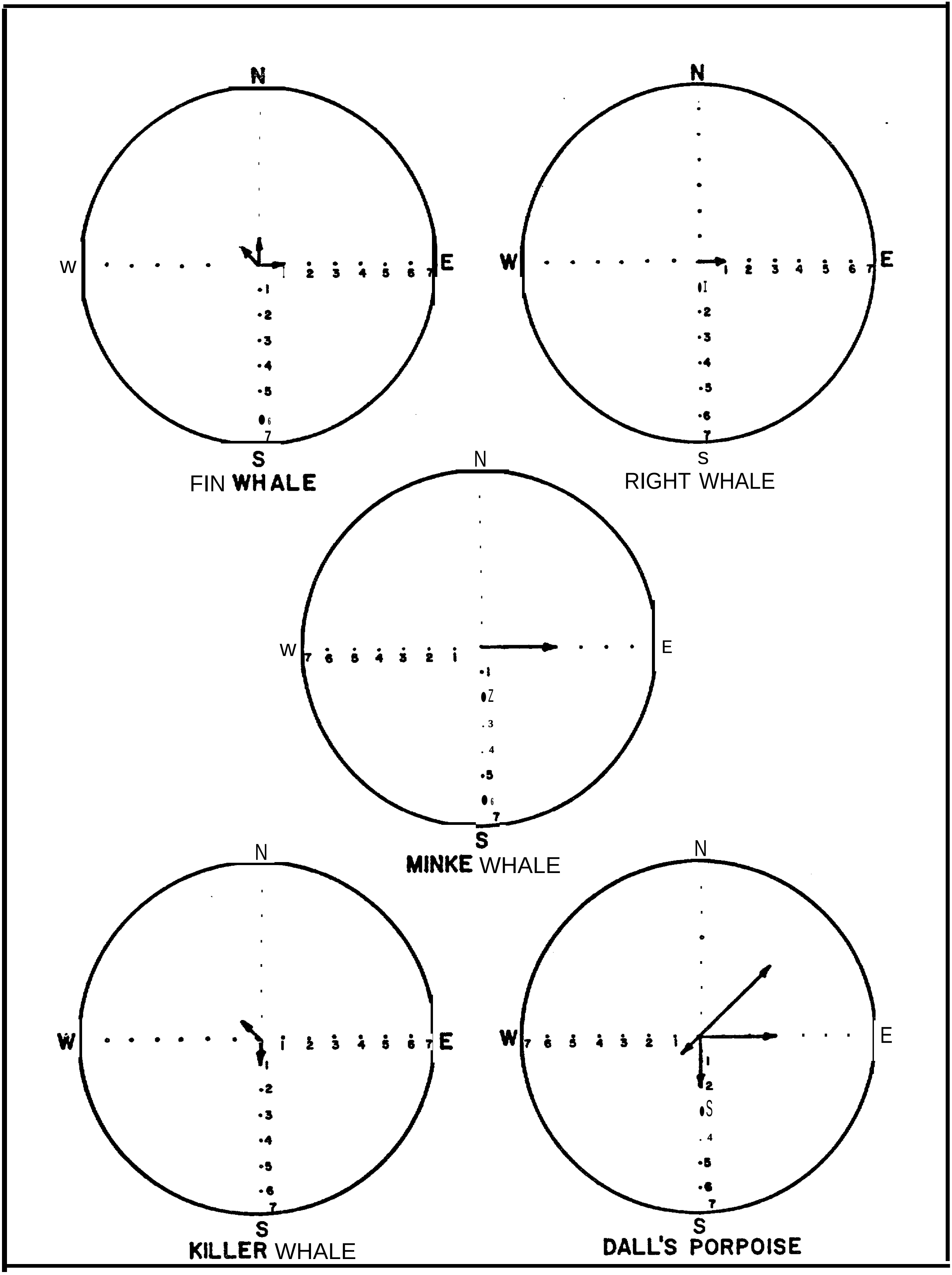

Figure 11 FREQUENCY OF WHALES OBSERVED POINTED IN A GIVEN DIRECTION OF TRAVEL IN THE NAVARIN BASIN DURING SUMMER, JULY- AUGUST 1982.

TABLE 9

ESTIMATED ABUNDANCE OF WHALES IN THE NAVARIN BASIN DURING SUMMER, 20 JULY-19 AUGUST 1982

Zone	Sampling unit	Total area (nm2)	% area coverage Aerial	Vessel	Total	Fin whale Obs.[a] no.	Est. no.	Right whale Obs. no.	Est. no.	Killer whale Obs. no.	Est. no.	Total Obs. no.	Est. no.
Shallow water	1	2463	9.8	0.2	10.0	-[b]	-				-	-	-
	5	2458	10.4	0	10.4	4	38			2	19	6	57
	6	2458	5.4	2.4	7.8			2	26			2	26
	8	2452	3.1	0	3.1						.	.	
	11	2461	0.5	1.1	1.6	-	-	-	-	-	-	-	-
Subtotal		12,292	5.8	0.7	6.5	4	38	2	26	2	19	8	83
All units		27,048	2.6	0.3	2.9		84		57		42		183
Transition	9	2461	4.3	0	4.3								
	22	2461	0	1.6	1.6								
Subtotal		4922	2.1	0.8	2.9		-	-		-	-		
All units		19,651	0.5	0.2	0.7								
Deep water	20	2461	5.5	0	5.5								
Subtotal		2461	5.5	0	5.5			-	-	-	-	-	-
All units		7379	1.8	0	1.8								
TOTAL		54,078	1.8	0.2	2.0	4	84 ± 184[c]	2	57 ± 118	2	42 ± 118	8	183

a/ Number of whales recorded in survey strip.
b/ Dash (-) signifies no animals.
c/ Ninety-five percent confidence interval.

in the transition zone. Abundance was not estimated for Dall's porpoise because of insufficient amount of trackline surveyed and no minke whales were encountered in the survey strip. The confidence limits of these estimates were wide because of small sample sizes. The estimates do not reflect the number of whales below the surface or otherwise missed during the surveys.

FALL SURVEY PERIOD

During the fall survey period, 136 whales comprising five species were recorded during 1,575 nm of aerial and vessel surveys (Table 10). As with the previous two survey periods, the Dan's porpoise was most abundant, followed by gray, killer, fin, and minke whales; three unidentified baleen whales were also recorded. All of these species, except for the unidentified baleen whales and the majority of the Dan's porpoises, were observed from the aircraft. Approximately 99 percent of the 1,346 nm of systematic trackline surveyed was by helicopter and the remainder by vessel; vessel surveys were also conducted along 229 nm of opportunistic trackline in the Basin.

Five sampling units were surveyed in the Basin (Table 10). Four units were in the shallow water zone and one in the transition zone; no surveys were done in the deep water zone because of persistent high seas. Survey effort in these zones relative to total trackline covered was 80 percent in the shallow water zone and 20 percent in the transition zone. Aerial surveys represented the primary survey platform in each zone, with virtually the entire 270 nm of trackline in each sampling unit censused.

Sea state and visibility conditions were generally conducive to obtaining accurate censuses of whales during 7 of the 20 day fall field period (Table 11). Visibility conditions were good or better during 81 percent of the survey time, which included glare less than 50 percent. Wind speeds averaged 13 kt and sea states below Beaufort 3 occurred 86 percent of the survey time. None of the units surveyed were

TABLE 10

NUMBER Of WALES OBSERVED DURING THE FALL AERIAL ANO VESSEL SURVEYS
OF TNE NAVARIN BASIN, 29 OCTOBER - 12 NOVEMBER 1982

Zone	Sampling unit	Track line distance surveyed[a/] Aerial (%)	Vessel (%)	Total (nm)	Fin whale No. obs	Fin whale No. indiv	Gray whale No. obs	Gray whale No. indiv	Minke whale No. obs	Minke whale No. indiv	Killer whale No. obs	Killer whale No. indiv	Unid. whale No. obs	Unid. whale No. indiv	Dall's porpoise No. obs	Dall's porpoise No. indiv	Total No. obs	Total No. indiv
Shallow water	1	100	0	269 [52][b/]	5	13	18	44	1	1	1	.6	2	3	-[c/]	-	27	67
	5	94	6	270 [54]	-	-	.	.	-		-	-	-	-	5	20	5	20
	6	100	0	267 [61]	-	-	-	-	1	1	-	-	-	-		.	1	1
	11	100	0	270 [61]	-	-	-	-	1	1	-	-	-	-	3	19	4	20
Subtotal		99	1	1076 [229]	5	13	18	44	3	3	1	6	2	3	8	39	37	108
Transit Ion	22	100	0	270 [0]	-	-	-	-	-		2	11	-	-	2	17	4	28
Subtotal		100	0	270 [0]	-	-	-	-	-	.	2	11	-	-	2		4	28
Deep water		Zone not surveyed																
TOTM		99	1	1346 [229]	5	13	18	44	3	3	3	17	2	3	10	56	41	136

a/ Total track line length available in each sampling unit was 270 nm.

b/ Brackets [ ] Include nautical miles surveyed by the vessel during aerial surveys; Incidental marine" mammal sightings were recorded for determining species distribution in the Basin.

c/ Oash (-) signifies no animals were observed.

TABLE 11

VISIBILITY AND SEA STATE CONDITIONS DURING FALL AERIAL AND VESSEL SURVEYS OF MARINE MAMMALS IN THE NAVARIN BASIN, 29 OCTOBER-12 NOVEMBER 1982

Zone	Sampling unit	Beaufort wind scale (%) 0	1	2	3	4	5	6	Visibility conditions (%)[a] UN	O	FA	GO	G	EX	Total distance surveyed (nm)
Shallow water	1	-[b]	-	80	20	-	-	-			28	9	63		269
	5		-	50	28	22	-	-			7	17	76		270
	6			-	52	48	-	-			34	21	45		267
	11		-	67	33	-	-	-	_	1	11	38	50		270
Subtotal			-	50	33	17	-	-		T[c]	20	22	58		1076
Transition	22			-	100	-	-	-	_	_	13	11	76		270
Subtotal				-	100	-	-	-			13	11	76		270
Deep water		Zone was not surveyed													
TOTAL			-	39	47	14	-	-		T	19	19	62		1346

a/ UN = unacceptable, PO = poor, FA = fair, GO = good, VG = very good, and EX = excellent as defined in Appendix Table B-1.

b/ Dash (-) signifies Beaufort or visibility conditions did not occur.

c/ T signifies percentage less than 0.5.

predominated by marginal viewing conditions. Poor weather, however, prevailed during 13 of the 20 day field season (Appendix Table A-4). Furthermore, the scheduled length of the field period was reduced because of persistent storms.

Whales were seen in both zones surveyed in the Basin during fall (Figure 12). All of the species occurred in the shallow water zone, while only Dall's porpoises and killer whales were in the transition zone. Fin and gray whales occurred in 1 unit at depths averaging 65 m, whereas killer whales were in 2 units and minke and DalI's porpoises in 3 units. Killer whales occurred in water depths ranging between 78 and 2043 m, compared with 78 to 95 m for minke whales and 97 to 930m for Dall's porpoises. All five of these species, except Dall's porpoises, were encountered in sampling unit 1. Whales were recorded in every sampling unit surveyed.

Movement patterns of whales in the Basin during fall were indefinite because of the small sample sizes (Figure 13). Direction of movement observed for fin, gray, and killer whales, was primarily southward. Grays and fins were encountered in the same geographic vicinity feeding in groups averaging 2.4 (n=18) and 2.6 (n=5) animals, respectively. Killer whales travelled in groups averaging 5.7 (n=3) animals. Dall's porpoises showed no specific directionality in their movements while minkes travelled northerly and westerly. Dall's porpoise group sizes were 5.7 (n=6) and minkes occurred in singles. Movement patterns did not appear to be influenced by the survey platform, except for minkes and DalI's porpoises which may have been attracted to the vessel.

An estimated 1,548 large whales at a density of 33 animals per 1,000 nm^2 were in the Basin during fall (Table 12). This estimate was derived from observations of 41 animals along 1,342 nm of systematic transect line comprising 2.9 percent coverage of the Basin. Killer whales had the highest estimated abundance at 798 animals and minke

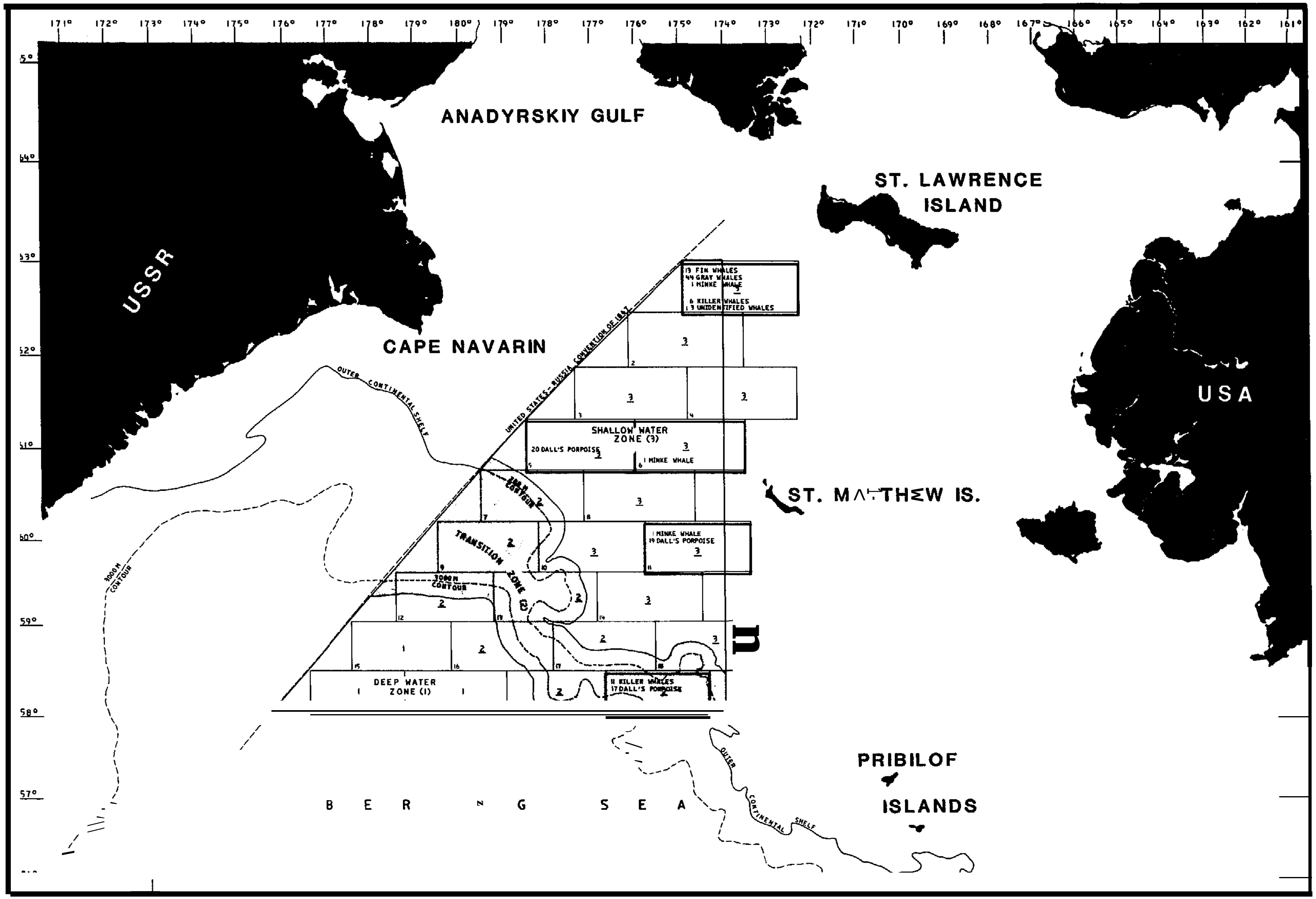

FIGURE 12 DISTRIBUTION OF WHALES IN THE FIVE SAMPLING UNITS SURVEYED IN THE NAVARIN BASIN DURING FALL, 29 OCTOBER - 12 NOVEMBER 1982 (SEE FIGURES 5 AND 6 AND TABLE 5 IN APPENDIX A FOR LOCATIONS OF SURVEY TRACKLINES AND ANIMALS).

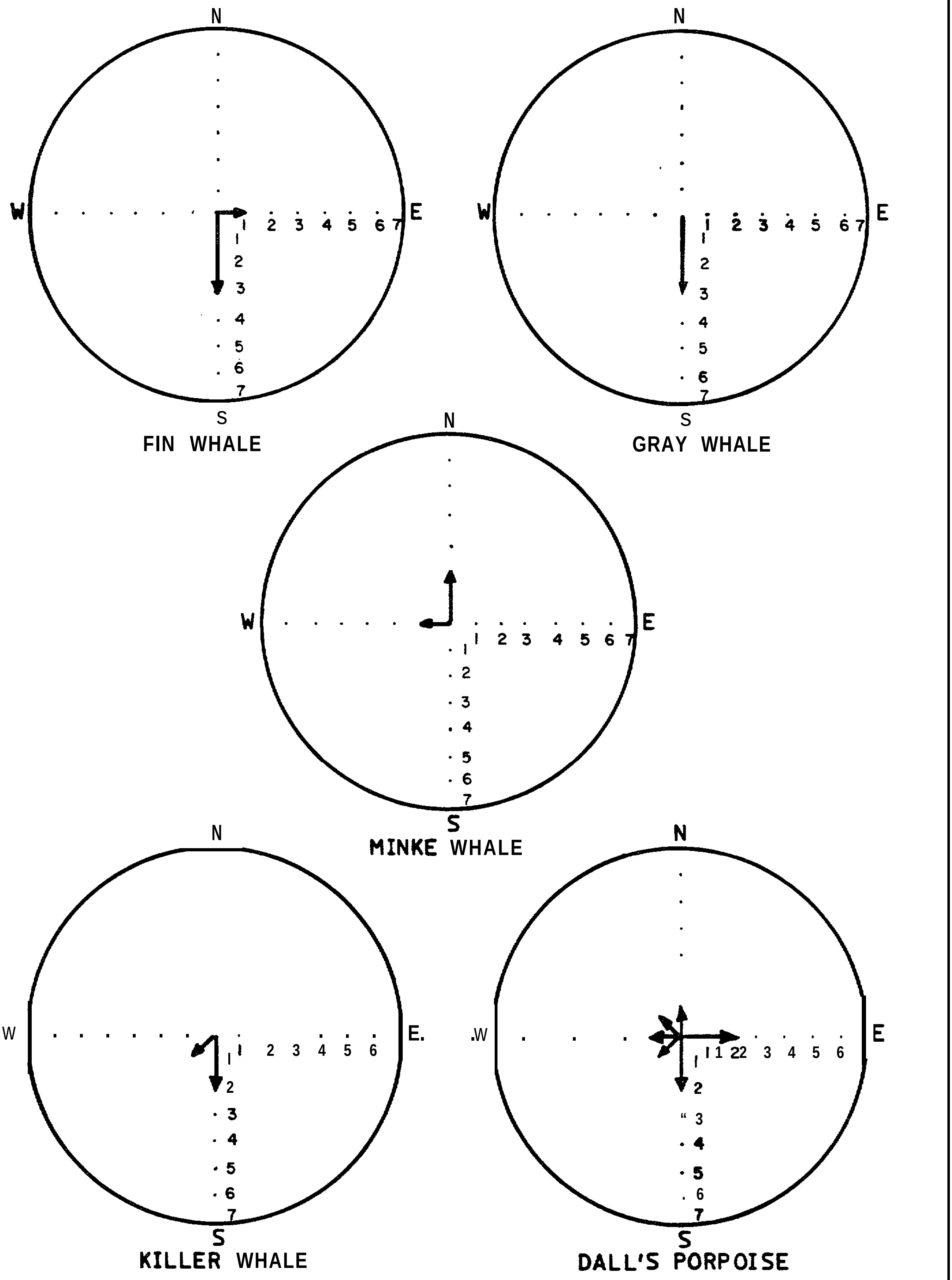

Figure 13 FREQUENCY OF WHALES OBSERVED POINTED IN A GIVEN DIRECTION OF TRAVEL IN THE NAVARIN BASIN DURING FALL, OCTOBER- NOVEMBER 1982.

TABLE 12

ESTIMATED ABUNDANCE OF WHALES IN THE NAVARIN BASIN DURING FALL, 29 OCTOBER - 12 NOVEMBER 1982

Zone	Sampling unit	Total area (nm^2)	% area coverage Aerial	Vessel	Total	Fin whale Obs.[a/] no.	Est. no.	Gray whale Obs. no.	Est. no.	Minke whale Obs. no.	Est. no.	Killer whale Obs. no.	Est. no.	Total Obs. no.	Est. no.
Shallow water	1	2463	11.0	0	11.0	9	82	20	182					29	264
	5	2458	10.4	0.5	10.9	-[b/]									
	6	2458	10.9	0	10.9					1	9			1	9
	11	2461	11.0	0	11.0		-	-	-	-	-	-	-	-	-
Subtotal		9840	10.8	0.1	10.9	9	82	20	182	1	9			30	273
All units		27,048	3.9	T[c/]	4.0		225		500		25				750
Transition	22	2461	11.0	0	11.0		-	-	-	-	-	11	100	11	100
Subtotal		2461	11.0	0	11.0							11	100	11	100
All units		19,651	1.4	0	1.4								798		798
Deep water		Not surveyed													
TOTAL		46,699	2.9	T	2.9	9	225 ± 520[d/]	20	500 ± 966	1	25 ± 48	11	798 ± 1558	41	1,548

[a/] Number of whales recorded in survey strip.
[b/] Dash (-) signifies no animals.
[c/] T signifies percentage less than 0.5.
[d/] Ninety-five percent confidence intervals.

whales the lowest estimated abundance at 25 animals. Fin and gray whale estimated abundances were intermediate at 225 and 500 whales, respectively. Dan's porpoises, while recorded in the Basin, were not enumerated because none were seen in the 0.5 nm survey strip. As noted for the other survey periods, confidence limits of the estimates were wide because of small sample sizes, and the estimates do not account for animals submerged or otherwise missed during the census.

WINTER SURVEY PERIOD

A total of 635 to 646 whales comprising 5 species were observed during 2,410 nm of aerial and vessel surveys in the marginal ice front of the Navarin Basin (Table 13). Over 90 percent of the whales recorded were beluga whales. In addition, there were 21 to 32 bowhead whales and 7 or fewer killer, fin, and minke whales. The latter three species were observed from the vessel and the majority of bowheads and belugas were recorded from the aircraft. Helicopter surveys accounted for over 68 percent of the trackline traversed in the 16,382 nm^2 defining the marginal ice front.

Six sampling units were surveyed which included four units in the Basin and two units immediately east of the Basin (Figure 4). The latter two units were surveyed to comply with an initial sampling strategy to census the entire marginal ice front between the Pribilof islands and Cape Olyutorskiy (USSR). This strategy was modified to terminate surveys at the US-USSR Convention Line when the USSR denied the USCG permission to enter their territorial waters. Aerial survey effort predominated in every unit except units 24 and 29, which were primarily censused from vessel because of weather (Table 13). Surveys were not conducted in the open water because of persisent high seas nor in the heavy pack ice because of mechanical difficulties with the icebreaker.

Environmental conditions were adequate to survey marine mammals during 250f the 30 day field season (Table 14). Visibility conditions were good to excellent 90 percent of the survey time. Marginal visibility prominated only in sampling unit 29. High winds, however, restricted

TABLE 13

NUMBER OF WHALES OBSERVED DURING THE WINTER AERIAL AND VESSEL SURVEYS
OF THE NAVARIN BASIN. 19 FEBRUARY - 18 MARCH 1983

Sampling unit	Trackline distance surveyed: Aerial (%)	Vessel	Total (nm)	Fin whale: No. obs	No. indiv	Bowhead whale[a]: No. obs	No. indiv	Minke whale: No. obs	No. indiv	Beluga whale: No. obs	No. indiv	Killer whale: No. obs	No. indiv	Unid. whale: No. obs	No. indiv	Total: no. obs	no. indiv
24		100	147	-[b]	-	-			-						-	-	-
25	82	18	462	-	-	3-10	5-12	-		4	36			1	2	8-15	43-50
26	71	29	613	-	-	4-8	16-20	-		25	562				-	30-34	578-582
27	83	17	482	-	-				-								
28	80	20	466	-	-												
29	23	77	240	1	6	-	-	1	1	-		1	7	-	-	3	14
TOTAL	68	32	2,410	1	6	7-18	21-32	1	1	29	598	1	7	1	2	40-51	635-646

a/ The range varies from a minimum number to a maximum number which includes possible duplicates.
b/ Dash (-) signifies no animals.

TABLE 14

VISIBILITY CONDITIONS AND WIND SPEED DURING WINTER AERIAL AND VESSEL SURVEYS OF MARINE MAMMALS IN THE NAVARIN BASIN, 19 FEBRUARY- **18 MARCH** 1983

Sampling unit	Visibility conditions (%)[a/]						Wind speed (%)			Total distance surveyed (rim)
	UN	PO	FA	GO	VG	EX	O-15kt	16-25 kt	>25 kt	
24	-[b/]	[b/] 4	11	36	38	11	-	8	92	147
25	-	1	6	16	50	27	37	58	5	462
26	-	1	3	44	36	16	41	38	21	613
27	-	3	5	70	18	4	60	33	8	482
28	-	2	2	19	17	60	6	84	10	466
29	2	19	26	53	-	-	-	39	61	240
TOTAL	T	3	7	40	28	22	31	48	22	2410

a/ UN · unacceptable, PO = poor, FA = fair, GO = good, VG = very good, and EX = excellent as defined in Appendix Table A-1.

b/ Dash (-) signifies that a visibility condition did not occur.

aerial surveys to 7 days. Wind speeds were particularly high during surveys of units 24 and 29, which were primarily censused from vessel. Vessel surveys were implemented whenever wind speeds exceeded 25 kt because of USCG flight restrictions. Even under conditions of high winds, whales were still sightable from the vessel since sea ice generally moderated the influence of wind on the water. The remaining five days of the survey period were for transiting to and from the study area (Appendix Table A-4).

Whales were observed in 3 of the 6 sampling units surveyed (Figure 4). Fin, minke, and killer whales exclusively occurred in sampling unit 29. The fin and minke whales were together in a single group in the ice fringe, near open water. The killer whales were also in a single group, but in the ice front where spotted seals were relatively abundant. Sampling units 25 and 26 contained populations of bowhead and beluga whales. Although these species were more widespread than the others, they were largely concentrated along the western fringe of the St. Matthew Island polynya; however, no whales were seen in the polynya proper. Neither were any whales observed in sampling units 24, 27, or 28. The two unidentified whales were probably bowheads, judging from their large size and close proximity to the other bowheads encountered.

Movement patterns of whales were variable during winter (Figure 14). Bowhead whales showed no specific direction of movement. The animals were observed in group sizes averaging 1.78 (n = 18, sd = 2.60), although 1 group of 12 animals was recorded. Beluga whales were similarly non-specific in their observed movement patterns. They did, however, display a penchant toward moving northward, with one group of over 400 animals recorded traveling that direction. Average group size for belugas was 20.62 animals (n = 29, sd = 75.50). Data on direction of movement for the fin, minke, and killer whales were quite inconclusive, since only one observation was made for each of these species.

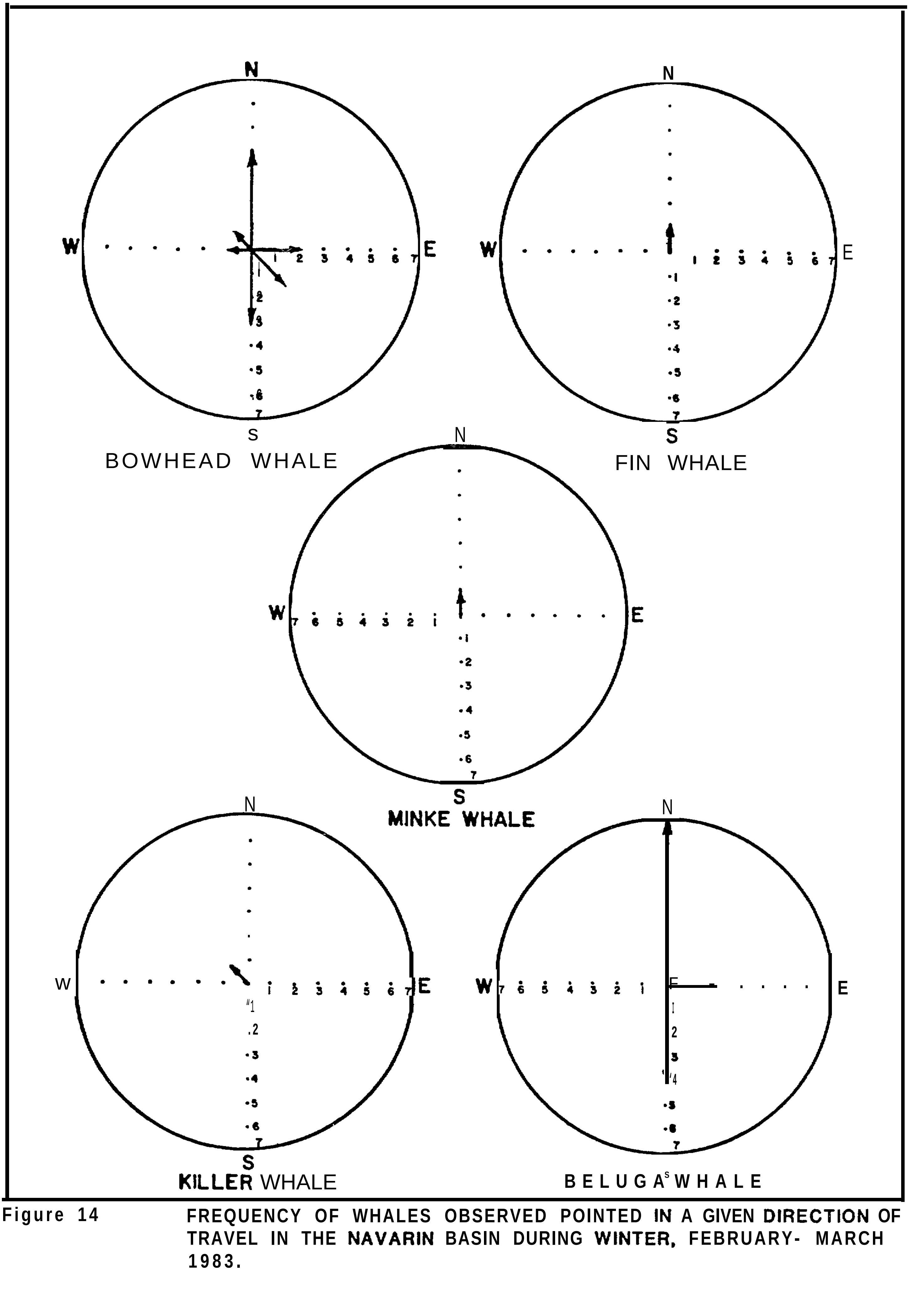

Figure 14 FREQUENCY OF WHALES OBSERVED POINTED IN A GIVEN DIRECTION OF TRAVEL IN THE NAVARIN BASIN DURING WINTER, FEBRUARY- MARCH 1983.

Ice coverage during the winter survey period was more extensive than average (Figure 15). The ice edge location was south of the 1954-70, 16 year mean (Potocsky 1975). The position of the ice edge resulted in approximately half of the Basin being covered in pack ice. The configuration Of the pack ice was typical, since it tended to follow the edge of the outer continental shelf.

Ice coverage in the marginal ice front during the winter surveys averaged 76 percent (Table 15). Ice coverage in the sampling units increased from 68 percent in the western unit (29) to approximately 80 percent in the eastern units (24, 25). One way ANOVA (following arcsine transformation) indicated that the difference among units was significant ($F = 14.78$, 5,837 df, $p < .001$). Ice in the western units was more broken, having large proportions of area in the lower ice concentration and size categories but relatively thick ice. Ice in the eastern units was relatively thin but more compacted, having large amounts of area in the highest ice concentration and size categories. This was particularly apparent in sampling units 25 and 26where almost 75 percent of the ice was new or young. These two units also contained all of the bowhead and beluga whales recorded during the survey period. Although the other whale species were encountered in sampling unit 29 where ice was thickest, the whales were near or in open water.

Bowhead and beluga whales were primarily observed in areas of thin but extensive ice coverage (Figure 16). Almost 90 percent of the bowhead and beluga whale observations were in areas of 80-100 percent ice concentration, predominated by new and young ice (Table 16). Few whales were observed in the lower ice concentrations, particularly the O-20 percent category, and there were no whales encountered in areas of thin to medium first year ice. Floe size did not appear to influence bowhead or beluga habitat use patterns. Too few bowhead or beluga whales were observed to statistically substantiate these observations.

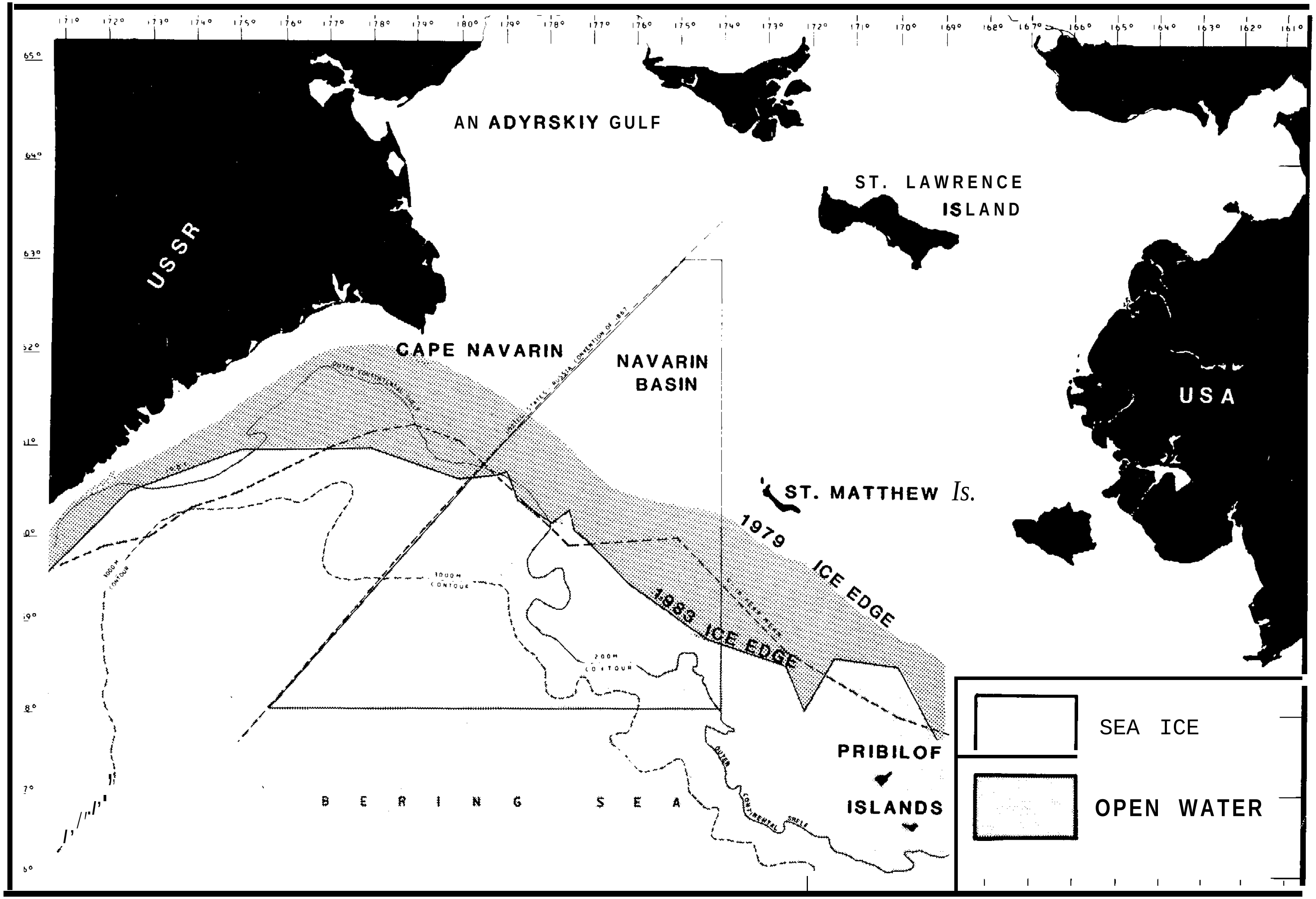

Figure 11 APPROXIMATE LOCATION OF ICE EDGE DURING 1979 AND 1983 STUDY PERIODS COMPARED TO A 5-16 YEAR MEAN (Potocsky 1975) IN THE BERING SEA.

TABLE 15

ICE CHARACTERISTICS OF STUDY AREA, 19 FEBRUARY - 18 MARCH 1983[a/]

Sampling unit	Percent area coverage of ice	Percent area (nm^2) coverage of each ice concentration category					Percent area coverage of each ice size category				Percent area coverage of each ice thickness category			Total area surveyed (nm^2)
		0-20	21-40	41-60	61-80	81-100	Grease-brash	Pancake-small	Medium-large	Vast-giant	New	Young	First year	
24	79.0	2.0	7.1	15.1	25.3	50.5	4.8	4.5	5.6	85.1	19.1	11.7	69.2	73.4
25	80.5	0.6	4.5	12.8	35.7	46.4	17.3	0.0	8.8	73.9	28.2	45.6	26.2	231.2
26	78.5	2.0	3.8	19.4	25.9	48.9	17.1	5.2	15.7	62.0	17.9	55.6	26.5	306.4
27	71.5	9.3	3.9	21.9	23.8	41.1	2.7	59.2	20.0	18.1	1.9	30.3	67.8	240.9
28	75.7	3.0	3.5	18.1	38.4	37.0	4.1	24.0	30.8	41.1	0.6	29.5	69.9	233.0
29	68.2	11.7	13.5	12.2	24.2	38.4	3.9	40.2	15.8	40.1	1.7	35.0	63.3	119.9
TOTAL	75.9	4.4	5.1	17.3	29.6	43.6	10.0	21.0	17.4	51.6	11.8	38.8	49.4	1204.8

a/ Ice characteristics are defined in Appendix Table A-3.

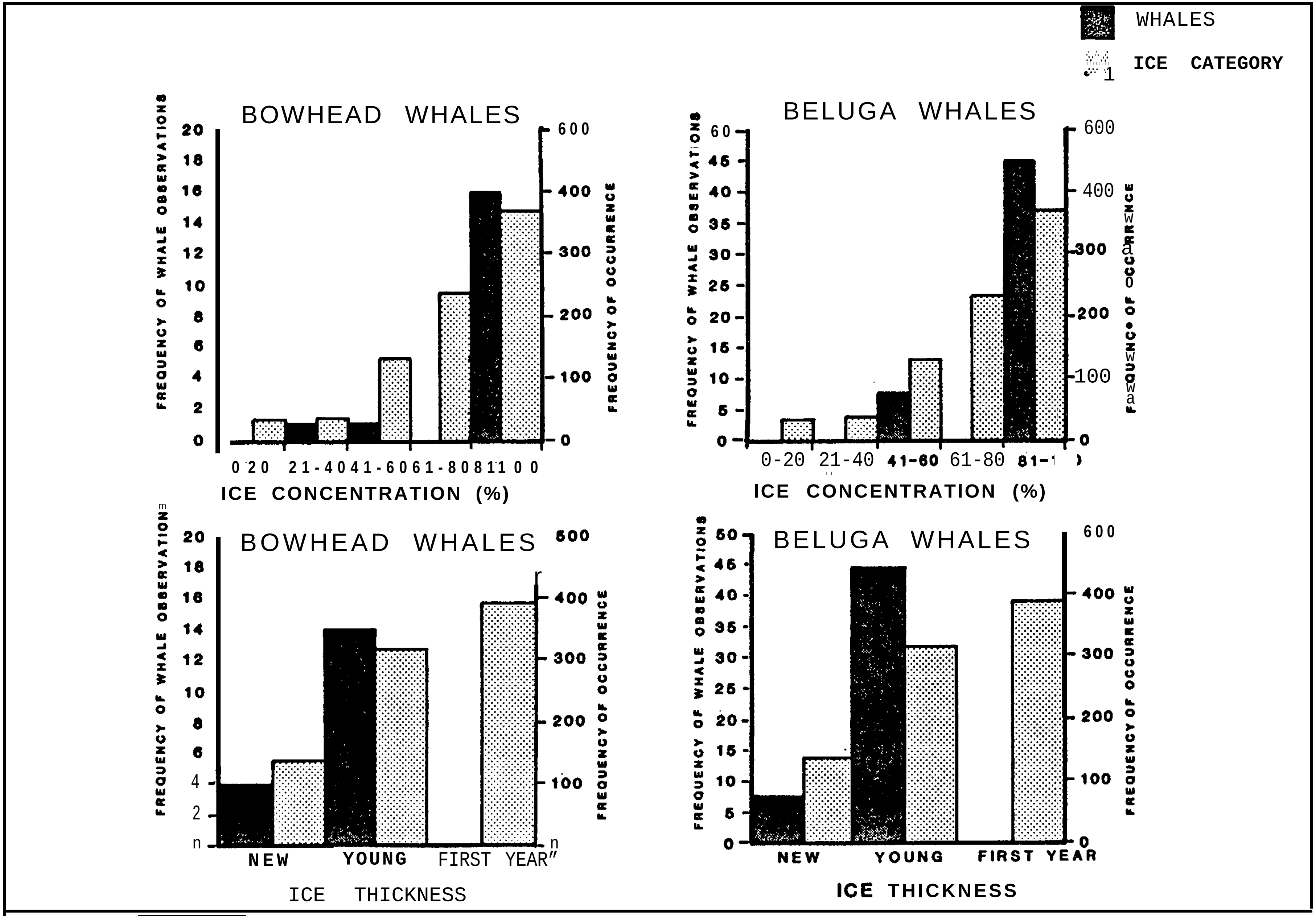

Figure 16 FREQUENCY OF WHALE OBSERVATIONS RELATIVE TO FREQUENCY OF ICE CONCENTRATION AND THICKNESS.

TABLE 16

NUMBER OF BOWHEAD AND BELUGA WHALES OBSERVED IN DIFFERENT ICE CONCENTRATION AND THICKNESS CATEGORIES

Ice concentration		Bowhead whales		Beluga whales	
Category	Freq.[a]	Number observed	Number of groups	Number observed	Number of groups
0-20%	36	0	0	0	0
21-40%	41	1	1	0	0
41-60%	139	1	1	7	2
61-80%	236	0	0	0	0
81-100%	351	16	7	45	12
TOTAL	803	18	9	52	14

Ice thickness		Bowhead whales		Beluga whales	
Category	Freq.[a]	Number observed	Number of groups	Number observed	Number of groups
New (< 10 cm)	95	4	4	2	6
Young (10-30cm)	312	5	5	12	20
First year (> 30 cm)	396	0	0	0	26
TOTAL	803	18	9	14	52

[a] Frequency of occurrence of each ice condition in a 3 nm survey unit along a transect line. Each trackline was partitioned in to approximately 10, 3 nm units.

An estimated 792 whales or 48 animals per 1,000 nm^2 wintered in the marginal ice front (Table 17). Fifty-eight whales were observed in the 6.7 percent area covered to calculate this estimate. Beluga whale abundance was estimated at 462 animals compared to 171 bowhead, 136 fin, and 23minke whales; no killer whales were observed within the strip during acceptable viewing conditions. The confidence intervals around these estimates were expectedly wide because of small sample sizes and clumped distributions.

TABLE 17

ESTIMATED ABUNDANCE OF WHALES IN THE NAVARIN BASIN DURING WINTER, 19 FEBRUARY - 18 MARCH 1983

Sampling unit	Total area (nm^2)	% area coverage Aerial	Vessel	Total	Fin whale Obs.[a] no.	Est. no.	Bowhead whale Obs. no.	Est. no.	Minke whale Obs. no.	Est. no.	Beluga whale Obs. no.	Est. no.	Total Obs. no.	Est. no.
24	2924	-	2.1	2.1	-[b]		-	- -						
25	2381	8.0	1.1	9.1			3	33					3	33
26	3731	5.7	2.3	8.0	-	-	11	138			37	462	48	600
27	3429	5.8	0.8	6.6	-	-	-	-						
28	2443	7.6	1.5	9.1										
29	1474	1.9	2.5	4.4	6	136	-	-	1	23	-	-	7	159
TOTAL	16,382	5.0	1.7	6.7	6	136	14	171	1	23	37	462	58	792
						±259[c]		±113		±43		±578		

a/ Number of whales recorded in survey strip.
b/ Dash (-) signifies no animals.
c/ Ninety-five percent confidence intervals.

DISCUSSION

The environmental conditions and whale species recorded during the four seasonal surveys define two ecological periods. The open water period encompasses the time frame of the spring, summer, and fall seasons. This period is characterized primarily by a virtual absence of sea ice in the Basin, except during early spring. The Basin at this time serves as a feeding ground for whales that winter in lower latitudes. Conversely, sea ice largely covers the Basin during the winter season. During this seasonal ice period bowhead and beluga whales, in association with numerous pinniped species, migrate from the northern latitudes to winter in the Basin. Since the seasonal ice period and ice-free period differ so dramatically in their environmental conditions and species composition, the results of the seasonal surveys in the Basin will be discussed according to these two periods.

ICE-FREE PERIOD

Seasonal abundance and species composition varied during the ice-free period. A total of six species of whales were observed in the Basin. Fin, minke, and killer whales, and DalI's porpoises were consistently observed each season. Right whales were encountered only during the summer season and gray whales only during the fall season. Species diversity was greatest in the summer and fall and lowest in the spring when survey effort was highest.

The density of large whales in the Basin was highest during fall and lowest during summer. An observed density of 33 whales per 1,000 nm^2 was estimated for fall compared to 16 whales per 1,000 nm^2 in spring and 3 whales per 1,000 nm^2 in summer. Species with the highest density for a given season was the killer whale, followed by the gray, fin, minke, and right whales. Densities for species encountered each season were greatest in the spring and fall and lowest in the summer. Although Dan's porpoises were the most commonly recorded species each season, seasonal densities were not calculated because most observations were outside the census strip. A pooled estimate of

Dan’s porpoise density for all seasons was 48 animals per 1,000 nm^2 or 2,623 animals (± 2,499) for 17 animals based on over 350 nm of vessel trackline surveyed during acceptable viewing conditions. These density estimates do not account for animals below the surface of the water or otherwise missed during the survey.

Whales were most abundant and diverse in the shallow water zone of the outer continental shelf each season (Figure 17). Fin, gray, and right whales were exclusively observed in this zone. Although right and gray whales were encountered in only one sampling unit, fin whales were observed in three different units, suggesting they were more widespread in their distribution than the other endangered species. Also observed in this zone were killer whales and minke whales. In addition, killer whales occurred in the transition zone, and minke whales in the deep water zone. Dan’s porpoises were the only species found in all three zones. Moreover, DalI’s porpoises were observed in more sampling units during each season than any other cetacean species. The distribution of all whales in these three zones differed significantly ($X^2 = 27.8$, 2df, p 0.001) from uniformity.

Seasonal movement patterns of whales in the Basin suggested directional trends for some species although the sample sizes were small. Trends were possible to examine only for fin, minke, and killer whales and Dan’s porpoises; right and gray whales were observed in the Basin only one season. Fin whale movement patterns were in a northwesterly direction in the spring, varied in the summer, and southeasterly in the fall. Movements of minke whales were northwesterly in the spring and fall, and easterly in the summer. Killer whales were encountered moving primarily in a northerly direction in the spring, southerly in fall, but in no specific direction in summer. Dan’s porpoises displayed no consistent movement orientation during any season. While the movement patterns of the Dan’s porpoise and minke whale may have been influenced by the vessel, since they were primarily recorded during vessel surveys, the other species showed no obvious negative reaction to the aircraft.

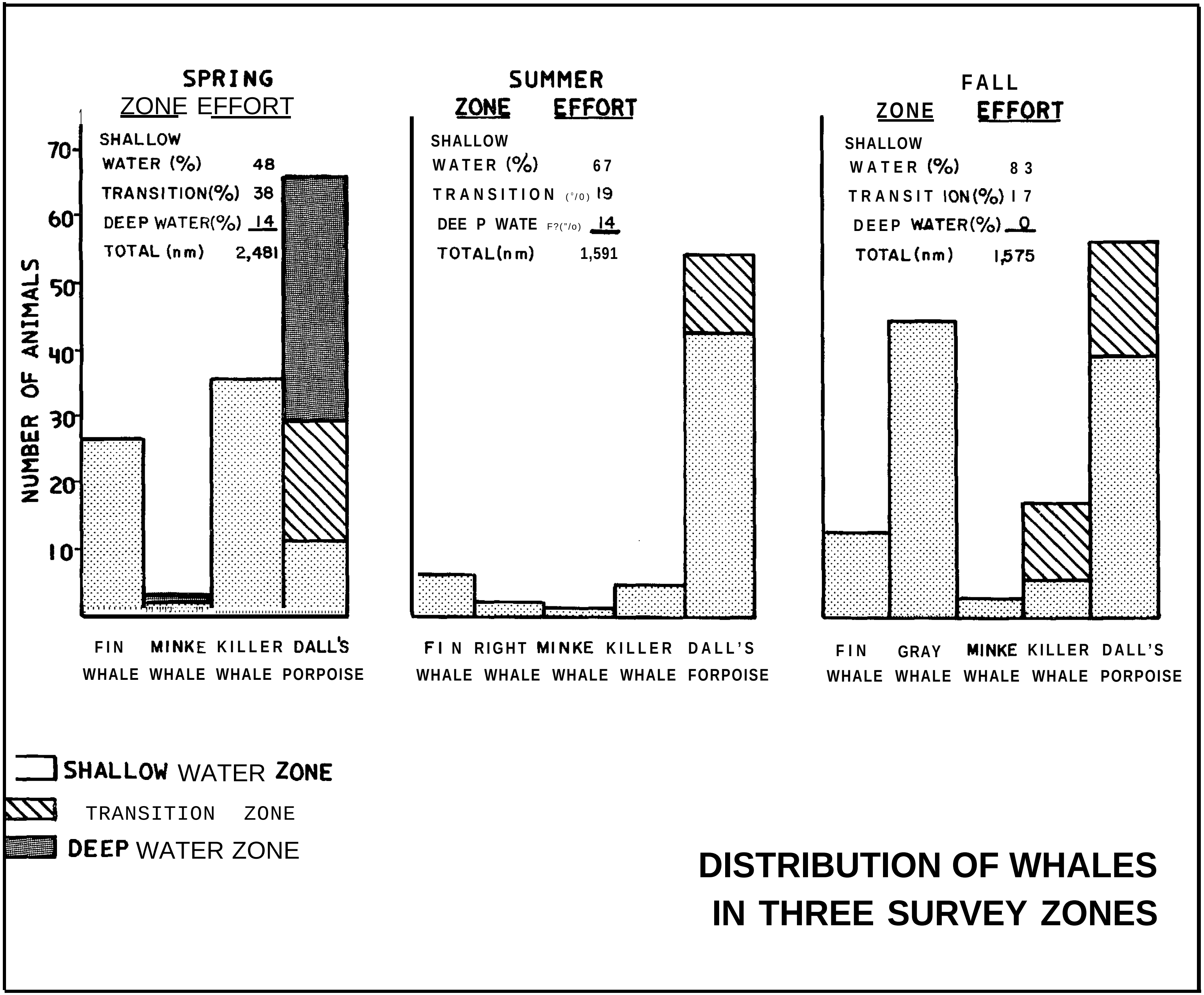

Figure 17 DISTRIBUTION OF WHALES AND PORPOISES IN THE THREE SURVEY ZONES OF THE NAVARIN BASIN DURING THE ICE-FREE PERIOD.

Most whales recorded in the Basin traveled in relatively large aggregations with animals clustered in small group sizes. This was particularly the case for fin and gray whales. In the spring, all 26 fin whales were within a 7 nm wide area, in the summer all 6 fins were in a 3 nm wide area, but in the fall they were more widespread. The average group size of 2.3 animals, however, did not differ significantly among seasons. The same situation was observed for gray and to a lesser degree killer whales which had average group sizes of 2.4 and 4.1 animals, respectively. All 44 gray whales were observed within approximately a 10 nm wide area and 25 of 35 killer whales within a 1 nm wide area; killer whales were widespread during the other seasons. Minke whales were very solitary, traveling as single animals each season. Less solitary, but widespread were Dall's porpoises, which were in group sizes averaging 3.9 animals. There was one observation of two right whales.

The combined results of the three seasonal surveys suggest that the Navarin Basin is a feeding area for species migrating through or summering in the Basin. Fin, right, minke, and killer whales and hall's porpoises probably were resident in the Basin during the ice free period, while gray whales and some fin whales migrated through areas of the Basin to or from their feeding grounds. Fin whale occurrence and movements observed in the Basin agree with and expand upon reported findings that these whales migrate through the Basin in the spring to feed in the Gulf of Anadyr and in the fall to their wintering grounds in the Pacific Ocean, while some summer west of St. Matthew Island andoff Cape Navarin (Berzin and Rovnin 1966, Nasu 1966, Nishiwaki 1974, Votorgov and Ivashin 1980, and Wada 1981). We observed fin whales moving toward the Gulfof Anadyr in the spring and away from the Basin in the fall, feeding in large aggregations. Conversely, fin whales observed during summer showed no directionality in their movements to suggest movement out of the Basin. Movements ofminke and killer whales were less clear, but their irregular seasonal directionality and presence each season coincided with reports that these species probably reside in the Basin throughout the ice-free period (Lowry et al. 1982). Also resident were DalI's porpoises, as indicated by a consistent lack of directionality in movements and absence of large aggregations each season as documented in the literature by other researchers (Lowry et al. 1982, Bouchet 1982). The single season observations of right and gray whales suggested the former species may summer in historically used areas of the Basin (Scammon 1874, Townsend 1935, Wada 1981, Berzin and Doroshenko 1981), while gray whales seen in the fall moving through the northern third of the Basin in large aggregations and feeding, coincided with the timing of their fall migration from more northern summering grounds (Kuz'min and Berzin 1975, Braham In press, Rugh In press). Gray whales may have also summered in the Basin but were not encountered during the surveys because of the small proportion of the total area covered.

The distribution of whales in the Basin coincided with their reported feeding habits. Fin, right, and gray whales feed largely in shallow waters (Nemoto 1970). The former two species feed primarily on pelagic crustaceans including euphausiids and copepods (Tomilin 1957, Omura 1958, Klumov 1963, Nemoto 1959, Omura et al. 1969, Lowry et al. 1982), while gray whales feed on benthic invertebrates including gammarid amphipods (Pike 1962, Rice and Wolman 1971, Marquette and Braham 1982, Nerini and Oliver 1983). In years when euphausiids and copepods are not abundant in the Bering and Chukchi seas, fishes are of major importance in the diet of fin whales (Nemoto 1959, Klumov 1963). Correspondingly, we encountered these species of whales only on the shelf where waters are relatively shallow compared to the rest of the Basin and which typically support prey populations these species feed upon. The more generalized feeding habits of minke and killer whales and Dan's porpoises coincided with their wider distribution in the Basin. These species feed on squid, fishes, and euphausiids (only minke) which are distributed over the continental shelf, slope, and rise waters where these species occurred in the Basin (Nemoto 1959, Klumov 1963, Mizue et al. 1966, Nemoto 1970, Crawford 1981, Kajimura et al. 1980). Dan's porpoises were most widespread in the Basin and concurrently feed on the widest range of prey items (Crawford 1981). Some of the species may have been more widespread in the Basin than observed under the realized survey effort.

Estimated densities of whales observed in the Navarin Basin were compared to those reported by other researchers (Table 18). Caution must be taken in interpreting density comparisons for the following reasons: (1) all estimates are extremely variable with low degree of reliability, (2) estimation procedures vary, and (3) density estimates will differ greatly for stocks in feeding areas versus those obtained for the whole range of the species. For instance, North Atlantic Ocean estimates were derived from line-transect procedures, while those for the North Pacific Ocean and Gulf of Alaska were calculated from strip transect procedures; a combination of both procedures was used in estimates for the Bering Sea. The comparisons do, however, provide a relative index of abundance useful in describing the significance of the Navarin Basin to whales. Estimated densities of fin andminke whales in the Navarin Basin were below those reported in the North Atlantic Ocean (Scott et al. 1979), but were above those for right whales. Gulf of Alaska (Rice and Wolman 1982) estimates for fin whale densities were similar to the Basin, while those in the North Pacific Ocean (Nishiwaki 1974) were much lower; estimates for right and minke whales were not available for these two areas. Both estimated densities for gray whales and Dan's porpoises were below those reported for the Bering Sea (Bouchet 1982, Ljungblad et al. 1983). No comparable estimates were available for killer whales. Thus, estimated densities of whales in the Navarin Basin during the ice-free period were lower than elsewhere, except for fin and right whales, which were generally similar or higher. None of these estimates account for submerged animals.

TABLE 18

ESTIMATED DENSITIES OF WHALES AND PORPOISES REPORTED BY VARIOUS RESEARCHERS

Location	Source	Estimated density of whales and porpoises (no. per 100 nm^2)							
		Fin	Gray	Right	Bowhead	Minke	Killer	Beluga	Dall's
Bering Sea	Present study	0.62	1.07	0.11	1.04	0.05	1.71	2.82	4.85
N. Atlantic Ocean a/	Scott et al. (1979)	1.36	b/	0.04	-	0.20	-		
N. Pacific Ocean	Nishiwaki (1974)	0.04	-	-					
Gulf of Alaska	Rice and Wolman (1982)	0.67	-	-					
Bering Sea	Bouchet (1982)								21.62
Bering Sea	Ljungblad et al. (1983@		4.68	-	-	-	-	-	
Bering Sea (marginal ice front)	Brueggeman (1982)	-	-	-	1.79	-	-	-	
Bering Sea	Lowry et al. (1982) d/	-	-	.	-	-	.	2.46	

a/ Study area was outer continental shelf of western Atlantic Ocean.

b/ Dash signifies no estimates available.

c/ Estimate was derived by dividing number of gray whales by total area surveyed as presented in Ljungblad et al. (1983).

d/ Estimate was derived by dividing estimated average population size of 16,500 animals by area of Bering Sea; the actual density is probably higher.

SEASONAL ICE PERIOD

Five species of whales wintered in the marginal ice front of the Navarin Basin. Bowhead and beluga whales occurred inside the front, while fin, minke, and killer whales utilized the fringe of the front. The latter three species are characteristically not found deep in the front, whereas an estimated population of3,390 to 4,325 bowhead (IWC 1983) and 15,000 to 18,000 beluga (Lowry et al. 1982) whales winter in the sea ice of the Bering Sea (Brueggeman 1982). Consequently, to discuss abundance, distribution, and habitat use of ice covered areas by whales other than bowheads and belugas is inappropriate. Therefore, the discussion will center on these two species.

The distribution of bowheads and belugas in the marginal ice front appeared to be primarily influenced by ice conditions associated with the St. Matthew island polynya. Suitable ice conditions for whales to occupy occurred throughout the front. In areas where ice concentrations were high, the ice was generally thin. Correspondingly, areas having thick ice usually had low concentrations. In fact, bowheads and belugas were encountered in the areas having the more extensive coverage, although the ice was thin enough for whales to freely move around. Therefore, it appears that ice in addition to other environmental factor(s) determine what is attractive habitat for these animals.

Another important factor appears to be St. Matthew Island, which was near the location of the whales. St. Matthew Island provides the physical setting for the creation of a persistent polynya (Stirling and Cleator 1981). The winds, which persist from the northeast during winter-spring, blow the ice southwesterly off the Island, resulting in a polynya. The polynya consists of a substantial area of open water in combination with new ice surrounded by heavier, more concentrated ice. Since the polynya is a persistent source of relatively open water, marine mammals may use it as a refuge from heavier ice.

The distribution of bowhead and beluga whales corresponded closely to the western fringe of the polynya. Although no animals were encountered in the polynya, which was thoroughly surveyed, they could still escape to it if ice conditions became unsuitable (compacted). The other borders of the polynya did not contain whales because these areas were heavily rafted with ice; the rafting was heavy enough to make penetration difficult for the icebreaker. The absence of use of the polynya proper is unclear, but a combination of high winds and open water could develop fairly high seas, possibly stressful to the animals. The influence of rough seas would be less important in the summer, when food is readily available and fat reserves are higher.

Brueggeman (1982) in surveys of the marginal ice front and interior pack ice in 1979, found concentrations of bowheads west of St. Matthew Island as well as west of St. Lawrence Island. The whales were also closely aligned with the polynyas associated with these two islands as well as the leeward side of the USSR coast. Over 77 percent of 109 whales were near the two islands in 1979. The whales appeared to winter near the two islands, then migrate north in spring to the Chukchi Sea. Densities in 1979 were similar to those observed during 1983 for bowheads. Beluga densities were also comparable to those estimated in the Bering Sea (Lowry et al. 1982).

SUMMARY

Four endangered species of whales - fin, right, gray, and bowhead - utilized the Navarin Basin during the ice-free and seasonal ice periods. Fin and right whales summered in the Basin. Gray whales and some fin whales moved through the Basin to either summering or wintering grounds elsewhere. All three species inhabited the shelf waters where they fed in water depths consistent with their foraging characteristics. Although no endangered whales were encountered beyond the shelf, some animals may have migrated through the deeper waters but were missed during the surveys. Densities of these species in the Basin were variable. Other species summering in the Basin were minke whales, killer whales, and DalJ's porpoises.

Two endangered species of whales also wintered in the Navarin Basin during the seasonal ice period. Bowhead whales occurred in the marginal ice front while fin whales utilized the fringe ice of the front. The St. Matthew Island polynya appeared to be a refuge for bowhead whales from heavy ice conditions. These whales aligned themselves near the edge of the polynya. Surveys were not conducted in the open water or heavy pack ice of the Basin so the use of these areas by bowheads and fins was not known. Densities of bowheads in the Basin were similar to those reported in the literature for the Bering Sea ice front while comparable estimates for fin whales were not available since most winter south of the Aleutians. Other species of whales wintering in the Basin were minke, killer, and beluga whales.

In summary, fin whales utilized the Navarin Basin yearling, while bowheads wintered and right whales summered there. Gray whales moved through the northern third of the Basin during fall. Of the species not classified as endangered, killer and minke whales also occurred in the Basin each season of the year, while belugas were present during the seasonal ice period, and Dan's porpoises were present during the ice-free period. No other whales were observed in the Navarin Basin.

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APPENDIXA

APPENDIXA

APPENDIX TABLE 1
DEFINITION OF SURFACE VISIBILITY CATEGORIES
USED DURING AERIAL AND VESSEL SURVEYS[a/]

Category	Definition
Excellent	Surface of water calm, a high overcast solid enough to prevent sun glare. Beaufort= O, visibility greater than 5 km. Marine mammals will appear black against a uniform gray background.
Very good	May be a light surface ripple on the surface or slightly uneven lighting, but still relatively easy to distinguish animals at a distance. Beaufort = 1 or 2, visibility greater than 5 km.
Good	May be a light chop, some sun glare or dark shadows in part of survey track. Beaufort less than or equal to 3, visibility less than or equal to 5km. Animals up close (300 m or less) can still be detected and fairly readily identified.
Fair	Choppy waves with some slight whitecapping, sun glare or dark shadows in 50 percent or less of the survey track. Beaufort less than or equal to 4, visibility less than or equal to 1 km.
Poor	Wind in excess of 15 kt, waves over2 ft with whitecaps, sun glare may occur in over 50 percent of the survey track. Beaufort less than or equal to 5, visibility less than or equal to 500 m. Animals may be missed unless within 100 m of the survey trackline, identification difficult except for larger species.
Unacceptable	Wind in excess of 25 kt; waves over 3 ft high with pronounced whitecapping. Sun glare may or may not be present. Beaufort greater than or equal to 6 or visibility less than or equal to 300 m. Detection of any marine mammal unlikely unless observer is looking directly at the place where it surfaces. Identification very difficult due to improbability of seeing animal more than once.

a/ Surface visibility classification was taken from the National Marine Fisheries Service's Platform of Opportunities Program (Consiglieri and Bouchet 1981).

APPENDIX TABLE 2
DESCR1PTIONOF BEAUFORT SEA STATE SCALE
USED DURING AERIAL AND VESSEL SURVEYS

Seal e	Sea condition	Wave height (ft.)	Wind speed (kt)
0	Smooth and mirrorlike	0	0-1
1	Scale-like ripples without foam crests	1	1-3
2	Small short waveless; crests glass appearance and not breaking	2	4-6
3	Large waveJets; some crests break, foam of glassy appearance; occasional white foam crests	3	7-1o
4	Small waves become longer; fairly frequent white foam crests	4	11-16
5	Moderate waves more pronounced long form; many white foam crests; there may be some spray	6	17-21
6	Large waves form; white foam crests extensive; may be spray	10	22-27
7	Sea heaves; while foam from breaking waves blown in streaks in direction of wind; spin drift	14	28-33
8	Moderately high waves of greater lengths; edges of crests break into span drifts; foam blown in well marked streaks	18	34-40

APPENDIX TABLE 3

SEA ICE CLASSIFICATION USED DURING AERIAL AND VESSEL SURVEYS[a/]

Category	Description
Ice thickness	
New ice	**less than or equal to 10 cm**
Young ice	**10-30 cm**
1st year ice	**greater than or equal to 30 cm**
Ice type	
Grease ice	A later stage of freezing than **frazile** ice (fine **spicules** or plates of ice suspended in water) **when** the crystals have coagulated to form a soupy layer on the surface. Grease ice reflects little light, giving the sea a matt appearance.
S1 ush	**Snow which is saturated and mixed with water on ice surfaces, or as a** viscous floating mass in water after a heavy snowfall.
Pancake ice	Predominately circular pieces of ice from 30 cm-3 m in diameter, and up to about 10 cm in thickness, with raised rims due to the pieces striking against one another.
Floes	Any relatively flat piece of ice.
Small floe	less than 10 **m across**
Medium floe	**10-30 m** across
Large floe	30-100 m across
Vast floe	100-200 m across
Giant floe	greater than 200 m across
Ice Concentration	The ratio of tenths of the sea surface actually covered by ice to the total area of sea surface, both ice-covered and ice-free, at a specific location or over a defined area.

[a/] Ice description were taken from the World Meteorological Organization (1970). Ice floe sizes were modified from the World Meteorological Organization according to definitions of National Oceanic and Atmospheric Administration.

APPENDIX TABLE 4

SUMMARY OF EVENTS DURING THE FOUR FIELD SEASONS, 1982-1983

SPRINGFIELD SEASON

Date	Event
May 11	Left Kodiak Island for Navarin Basin
12	In transit to Navarin Basin
13	In transit to Navarin Basin
14	In transit to Navarin Basin
15	Arrived at St. Matthew Island to drop off U.S. Fish & Wildlife Service (USFWS) personnel but cancelled operation due to sea ice
16	Conducted vessel survey
17	Conducted vessel survey
18	Conducted aerial/vessel survey
19	Conducted aerial survey
20	Conducted aerial survey
21	Conducted aerial survey
22	Dropped off USFWS personnel at St. Matthew Island
23	Conducted aerial/vessel survey
24	Conducted vessel survey
25	Conducted vessel survey and left for Pribilof Islands to pick up Global Navigation System to replace one broken in helicopter
26	Left St. Paul for Navarin Basin
27	Arrived at Navarin Basin late in evening
28	Conducted aerial survey
29	Conducted aerial survey
30	Bad weather
June 1	Bad weather
2	Bad weather
3	Bad weather
4	Conducted vessel survey
5	Conducted aerial/vessel survey
6	Left Navarin Basin for Kodiak Island
7	In transit to Kodiak Island
8	In transit to Kodiak Island
9	In transitto Kodiak Island
10	Arrived at Kodiak Island

APPENDIX TABLE 4 (Continued)

SUMMER FIELD SEASON

July 20	Left Kodiak Island for Navarin Basin
21	In transit to Navarin Basin
22	In transit to Navarin Basin
23	In transit to Navarin Basin
24	In transit to Navarin Basin
25	Transferred USFWS personnel to St.. Matthew Island and conducted aerial survey
26	Conducted vessel survey
27	Conducted aerial/vessel survey
28	Conducted aerial survey
29	Conducted aerial/vessel survey
30	Bad weather, collected bathymetry
31	Conducted vessel survey
August 1	Left Navarin Basin for Nome to repair ship
2	Spent day in Nome
3	Left Nome for Navarin Basin
4	Conducted vessel survey
5	Conducted aerial survey and left Navarin Basin for Pribilof Islands to medical evacuate fishermen
6	Left Pribilof Islands for Navarin Basin
7	Conducted vessel survey
8	Conducted vessel survey
9	Bad weather, left Navarin Basin for Pribilof Islands to evacuate crewman for funeral
10	Left Pribilof Islands for Navarin Basin
11	Picked up USFWS personnel at St. Matthew Island
12	Picked up USFWS personnel at St. Matthew Island
13	Bad weather, collected bathymetry
14	Conducted aerial/vessel survey
15	Left Navarin Basin for Kodiak Island
16	In transit to Kodiak Island
17	In transit to Kodiak Island
18	In transit to Kodiak Island
19	Arrived at Kodiak Island

APPENDIX TABLE 4 (Continued)

FALL FIELD SEASON

October 26	Left Kodiak Island for Navarin Basin
27	In transit to Navarin Basin
28	In transit to Navarin Basin
29	Conducted aerial survey
30	Bad weather
31	Bad weather
November 1	Bad weather
2	Conducted aerial/vessel survey
3	Bad weather
4	Conducted aerial survey
5	Conducted aerial survey
6	Conducted aerial survey
7	Bad weather
8	Conducted aerial survey
9	Bad weather
10	Conducted aerial survey
11	Bad weather
12	Bad weather
13	Left Navarin Basin for Dutch Harbor at Captain Sandquest's decision because of bad weather
14	Arrived at Dutch Harbor

WINTER FIELD SEASON

February 18	Left Dutch Harbor for Navarin Basin
19	Arrived at ice edge in evening
20	Conducted vessel survey
21	Conducted vessel survey
22	Conducted vessel survey
23	Conducted vessel survey
24	Conducted vessel survey
25	Conducted vessel survey
26	Conducted vessel survey
27	Conducted vessel survey
28	Conducted vessel survey
March 1	Conducted vessel survey
2	Conducted vessel survey
3	Conducted aerial/vessel surveys
4	Conducted aerial survey
5	Conducted aerial survey
6	Conducted vessel survey
7	Conducted vessel survey
8	Conducted vessel survey
9	Conducted vessel survey
10	Conducted vessel survey

APPENDIX TABLE 4 (Continued)

March 11	Conducted vessel survey
12	Conducted aerial survey
13	Conducted aerial survey
14	Conducted aerial survey
15	Conducted aerial survey
16	Conducted vessel survey
17	Bad weather
18	Left Navarin Basin for Dutch Harbor
19	Arrived at Dutch Harbor

APPENDIX TABLE 5
RECORD OF MARINE MAMMALS ENCOUNTERED IN THE NAVARIN BASIN
DURING THE FOUR SURVEY SEASONS, MAY-JUNE, JULY-AUGUST,
OCTOBER-NOVEMBER 1982 AND FEBRUARY-MARCH 1983

SPRING SURVEY

Date	Species[a/]	Number	Location
5/21/82	OO	4	60° 10'N, 175° 41'W
5/21/82	PD	2	60° 06'N, 175° 38'W
5/21/82	OO	2	60° 07'N, 174° 34'W
5/21/82	OO	8	60° 07'N, 174° 34'W
5/21/82	OO	10	60° 07'N, 174° 34'W
5/21/82	OO	3	60° 07'N, 174° 34'W
5/21/82	OO	1	59° 55'N, 174° 29'W
5/21/82	OO	1	59° 55'N, 174° 29'W
5/21/82	OO	1	59° 45'N, 174° 18'W
5/21/82	OO	4	60° 01'N, 174° 18'W
5/28/82	PD	2	60° 18'N, 178° 36'W
5/29/82	BP	2	59° 47'N, 176° 59'W
5/29/82	BP	3	59° 46'N, 176° 59'W
5/29/82	BP	1	59° 46'N, 176° 59'W
5/29/82	BP	4	59° 46'N, 176° 59'W
5/29/82	BP	5	59° 46'N, 176° 59'W
5/29/82	BP	1	59° 46'N, 176° 59'W
5/29/82	BP	3	59° 46'N, 176° 59'W
5/29/82	BP	1	59° 41'N, 176° 59'W
5/29/82	BP	3	59° 41'N, 176° 59'W
5/29/82	BP	1	59° 41'N, 176° 59'W
5/29/82	BP	2	59° 40'N, 176° 43'W
5/17/82	PD	4	57° 49'N, 175° 9'W
5/17/82	PD	3	58° 10'N, 175° 9'W
5/17/82	PD	1	58° 14'N, 175° 25'W
5/18/82	PD	2	58° 08'N, 175° 55'W
5/18/82	PD	4	58° 07'N, 175° 55'W
5/19/82	PD	4	58° 13'N, 179° 32'W
5/20/82	PD	13	58° 13'N, 179° 00'E
5/20/82	BA	1	58° 13'N, 179° 29'E
5/20/82	PD	4	58° 13'N, 179° 42'E
5/20/82	PD	2	58° 13'N, 179° 46'E
5/20/82	PD	12	58° 13'N, 179° 47'E
5/20/82	PD	2	58° 13'N, 179° 49'E

a/ OO = killer whale, PO = Dall's porpoise, BP = fin whale, and BA = minke whale.

APPENDIX TABLE 5 (Continued)

SPRING SURVEY

Date	Species[a/]	Number	Location
5/21/82	00	1	59° 54'N, 174″ 37′W
5/24/82	BA	1	60° 40'N, 176° 24′W
5/24/82	PD	1	60° 20'N, 176° 41'W
5/24/82	PD	5	60° 21'N, 176° 41'W
5/24/82	PD	2	60° 33'N, 176″ 41'W
5/27/82	BA	1	60″ 45'N, 174″ 50'W
5/29/82	PD	2	59° 55'N, 176″ 24′W

APPENDIX TABLE 5 (Continued)

SUMMER SURVEY

Date	Species[a/]	Number	Location
7/28/82	BP	1	61° 03'N, 176″ 41'W
7/28/82	BP	2	61° 05'N, 176″ 41'W
7/28/82	BP	3	61″ 06'N, 176° 41'W
7/28/82	BP	1	61 ° 03'N, 176° 57'W
7/28/82	PD	3	61° 19'N, 177° 17'W
7/28/82	PD	4	61″ 20'N, 177″ 26'W
7/28/62	OU	3	61″ 03'N, 177″ 47'W
7/28/82	PD	5	61° 03'N, 177″ 47'W
7/28/82	PD	3	61° 11'N, 178° 21'W
7/29/82	PD	2	59° 59'N, 178" 51'W
7/26/82	BG	2	60" 48'N, 175° 18'W
7/28/82	PD	4	61° 03'N, 176″ 11'W
7/28/82	PD	5	61° 03'N, 176″ 12'W
7/28/82	PD	4	61° 03'N, 176° 18'W
7/28/82	BA	1	61° 03'N, 176″ 36'W
7/28/82	PD	1	61° 03'N, 176″ 43'W
7/28/82	PD	2	61° 03'N, 177° 04'W
7/28/82	PD	1	61° 03'N, 177″ 09'W
7/28/82	PD	3	61° 03'N, 177″ 12'W
7/28/82	PD	3	61″ 03'N, 177″ 18'W
7/29/82	PD	3	59° 55'N, 178° 49'W
7/31/82	PD	3	60° 03'N, 175° 22'W
7/31/82	PD	2	60″ 04'N, 175° 22'W
8/04/82	00	2	59° 40'N, 173° 30'W
8/08/82	PD	2	58″ 17'N, 174° 54'W
8/08/82	PD	4	57° 50'N, 175° 25'W

a/ BG · Pacific right whale.

APPENDIX TABLE 5 (Continued)

FALL SURVEY

Date	Species[a/]	Number	Location
10/29/82	PD	2	58° 30'N, 174° 44'W
10/29/82	00	6	58° 08'N, 175° 10'W
10/29/82	00	5	58° 08'N, 175° 10'W
10/29/82	PD	15	58° 21'N, 175° 10'W
11/2/82	PD	5	61° 03'N, 178° 21'W
11/4/82	BA	1	63° 00'N, 173° 35'W
11/4/82	BA	1	62° 57'N, 173° 35'W
11/4/82	00	6	62° 46'N, 173° 31'W
11/4/82	BP	2	62° 30'N, 173° 35'W
11/4/82	BP	2	62° 28'N, 173° 30'W
11/4/82	ER	2	62° 53'N, 173° 18'W
11/4/82	ER	5	62° 51'N, 173° 8'W
11/4/82	ER	7	62° 51'N, 173″ 8'W
11/4/82	ER	1	62° 52'N, 173° 8'W
11/4/82	ER	1	62° 54'N, 173″ 8'W
11/4/82	ER	1	52° 54'N, 173° 8'W
11/4/82	ER	2	62° 56'N, 173° 8'W
11/4/82	ER	1	62° 56'N, 173° 8'W
11/4/82	ER	5	62° 56'N, 173° 8'W
11/4/82	ER	1	62° 57'N, 173° 18'W
11/4/82	ER	1	62° 58'N, 173° 18'W
11/4/82	ER	1	62″ 58'N, 173° 18'W
11/4/82	ER	5	63° 00'N, 173° 18'W
11/4/82	ER	2	63° 00'N, 173° 18'W
11/4/82	ER	1	63° 01'N, 173° 12'W
11/4/82	ER	2	63° 01'N, 173° 07'W
11/4/82	ER	5	63° 01'N, 173″ 12'W
11/4/82	ER	1	63° 01'N, 173° 05'W
11/4/82	BP	2	62° 34'N, 173° 00'W
11/4/82	BP	4	62° 33'N, 173° 00'W
11/4/82	BP	3	62° 31'N, 173° 00'W
11/5/82	PD	1	61° 15'N, 176° 32'W
11/6/82	BA	1	61″ 13'N, 175° 17'W
11/10/82	BA	1	60° 10'N, 174° 30'W
11/10/82	PD	4	59° 39'N, 175° 21'W
11/4/82	UW	2	62° 45'N, 174° 21'W
11/4/82	UW	1	62″ 45'N, 173° 19'W
11/5/82	PD	3	61° 03'N, 176° 25'W
11/5/82	PD	5	61° 03'N, 177° 08'W
11/5/82	PD	6	61″ 03'N, 177° 33'W
11/10/82	PD	12	59″ 55'N, 173° 48'W
11/10/82	PD	3	59° 55'N, 175° 06'W

a/ ER = gray whale.

APPENDIX TABLE 5 (Continued)

WINTER SURVEY

Date	Species[a/]	Number[b/]	Location
3/3/83	6A	1	60° 41'N, 179″ 37'W
2/28/83	BP	6	60° 41'N, 179″ 37'W
2/28/83	00	6	60″ 55'N, 178° 17'W
2/28/83	00	1	60° 55'N, 178° 17'W
3/12/83	BM	3	60″ 17'N, 173° 52'W
3/1 2/83	BM	1	60° 09'N, 174″ 20'W
3/12/83	BM	1	60° 09'N, 174° 20'W
3/1 2/83	BM	12	59° 54'N, 174° 20'W
3/12/83	BM	2	60″ 00'N, 174° 28'W
3/1 3/83	BM	1	60° 04'N, 174″ 16'W
3/1 3/83	BM	1	60″ 04'N, 174° 16'W
3/1 3/83	BM	1	60″ 12'N, 174″ 04'W
3/1 3/83	BM	1	60° 14'N, 174° 01'W
3/1 3/83	BM	1	60° 12'N, 173° 56'W
3/1 3/83	BM	1	60° 17'N, 173″ 57'W
3/1 3/83	BM	1	60° 19'N, 173″ 56'W
3/1 3/83	BM	1	60° 10'N, 173° 52'W
3/13/83	BM	1	60° 09'N, 173″ 53'W
3/1 3/83	BM	1	60° 09'N, 173° 53'W
3/1 3/83	BM	1	60° 17'N, 173° 57'W
3/14/83	BM	1	60″ 35'N, 173″ 48'W
3/1 5/83	BM	1	59° 47'N, 173″ 24'W
3/12/83	DL	11	59° 58'N, 174″ 11'W
3/1 2/83	DL	4	59° 57'N, 174° 13'W
3/12/83	DL	5	59° 58'N, 174° 16'W
3/12/83	DL	2	59″ 58'N, 174° 16'W
3/1 2/83	DL	25	60″ 04'N, 174° 20'W
3/1 2/83	DL	2	60° 04'N, 174° 20'W
3/1 2/83	DL	2	60° 04'N, 174° 20'W
3/1 2/83	DL	6	59° 54'N, 174″ 20'W
3/1 2/83	DL	2	59″ 54'N, 174″ 20'W
3/1 2/83	DL	8	59° 56'N, 174° 20'W

a/ BM • Bowhead, DL = Beluga
b/ Duplicate counts of bowhead and beluga whales may have occurred during the 12 and 13 March surveys.

APPENDIX TABLE 5 (Continued)

WINTER SURVEY

Date	Species[a/]	Number[b/]	Location
3/12/83	DL	4	59″ 55'N, 174° 28'W
3/1 2/83	DL	1	59″ 55'N, 174° 28'W
3/1 2/83	DL	2	60° 00'N, 174″ 28'W
3/1 2/83	DL	12	59° 57'N, 174″ 28'W
3/12/83	DL	6	59° 55'N, 174° 32'W
3/12/83	DL	7	59° 55'N, 174° 32'W
3/1 2/83	DL	6	59° 54'N, 174° 32'W
3/12/83	DL	6	59° 56'N, 174″ 33'W
3/12/83	DL	2	59″ 56'N, 174° 33'W
3/1 2/83	DL	3	59″ 56'N, 174″ 33'W
3/1 2/83	DL	1	59″ 57'N, 174″ 33'W
3/1 2/83	DL	3	59″ 58'N, 174″ 32'W
3/12/83	DL	3	59° 58'N, 174″ 32'W
3/1 2/83	DL	6	59° 55'N, 174″ 32'W
3/1 3/83	DL	433	60° 19'N, 174″ 22'W
3/1 4/83	DL	13	60° 44'N, 173″ 50'W
3/1 4/83	DL	3	60° 44'N, 173″ 50'W
3/1 4/83	DL	18	60″ 44'N, 173″ 50'W
3/1 4/83	DL	2	60° 44'N, 173° 50'W

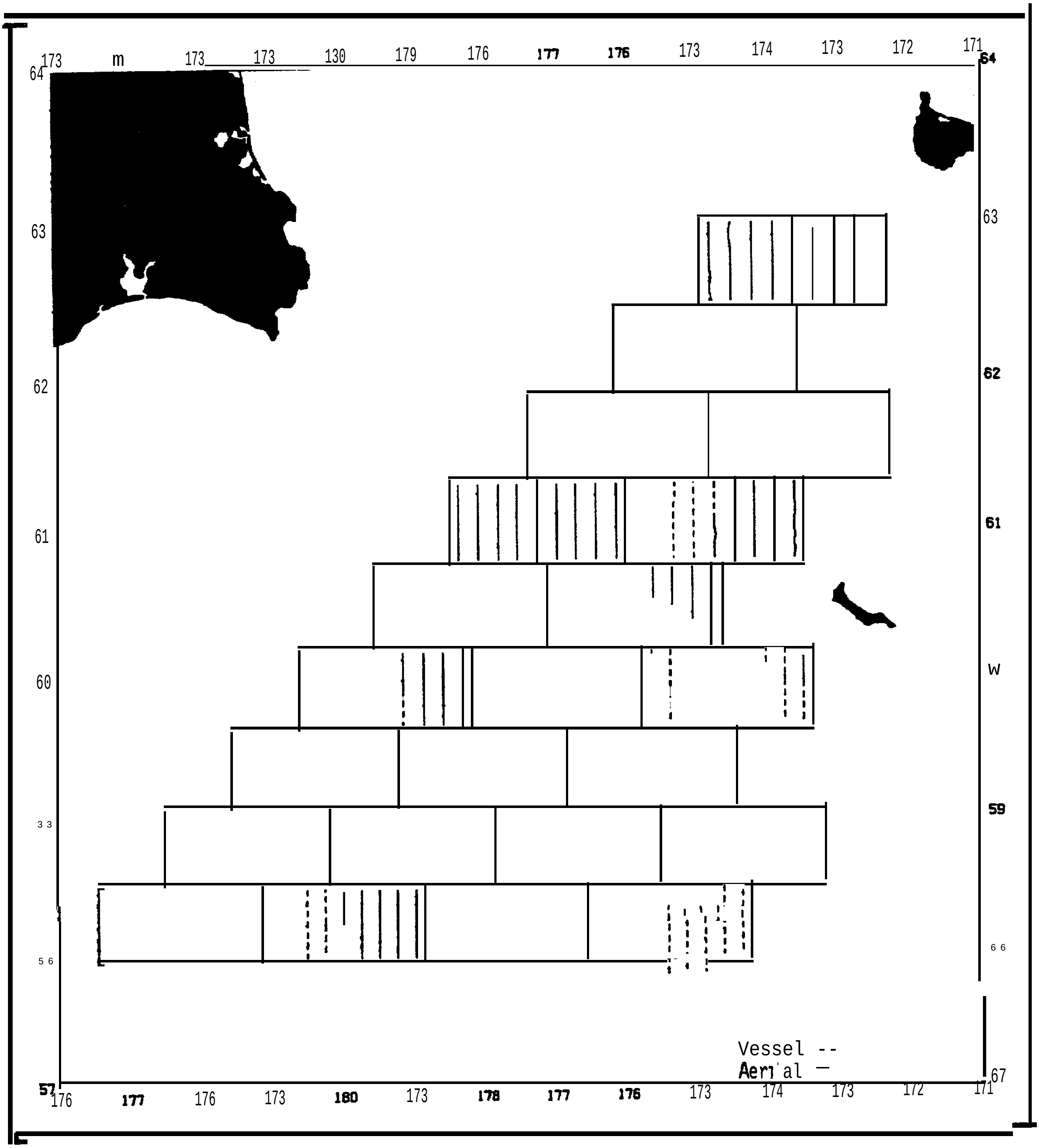


FIGURE 1 LOCATION OF AERIAL AND VESSEL TRACKLINES SURVEYED IN THE NAVARIN BASIN DURING SPRING, MAY- JUNE 1982-

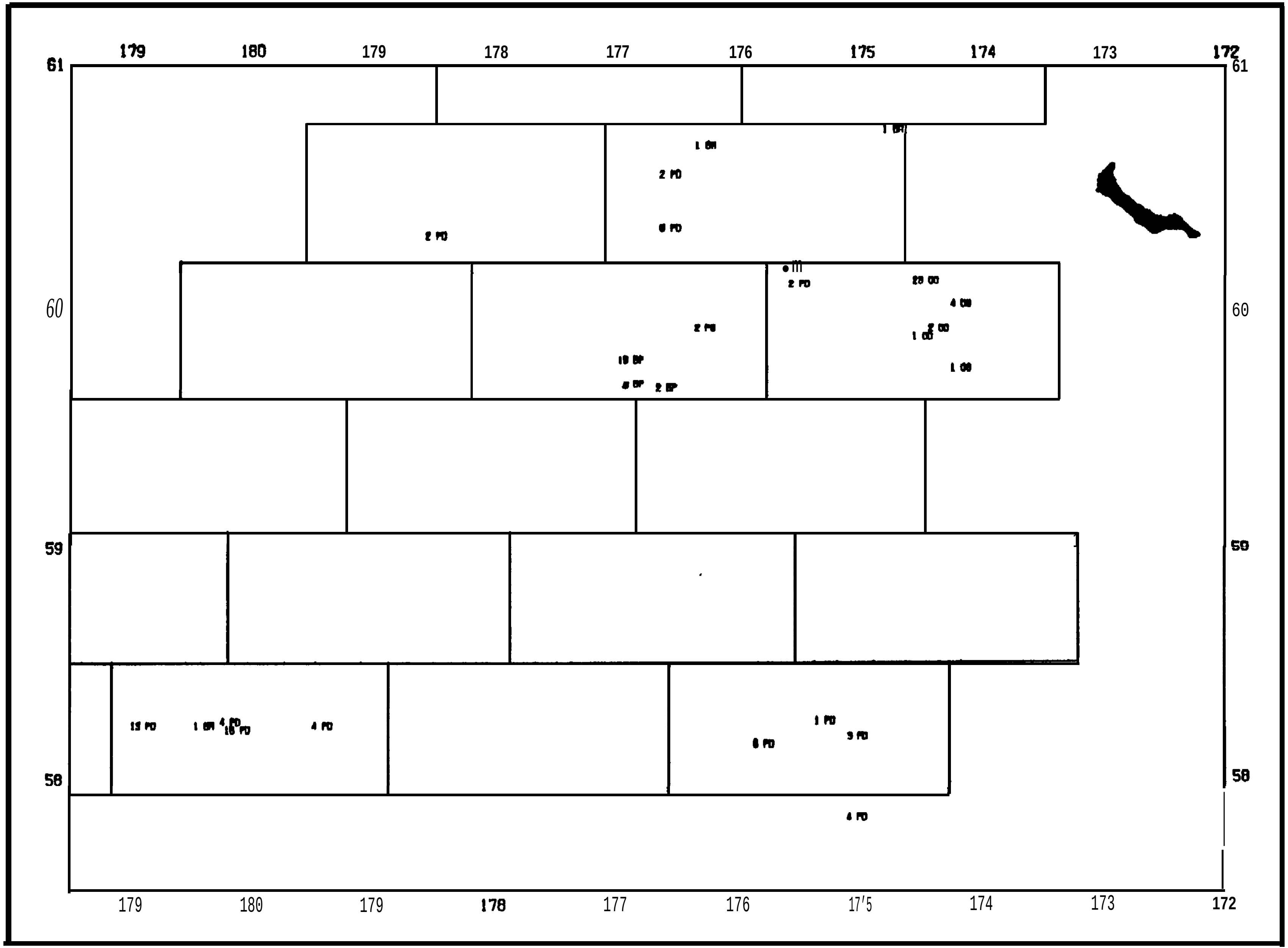


FIGURE 2 LOCATION OF WHALES OBSERVED IN THE NAVARIN BASIN DURING THE SPRING SURVEYS, MAY - JUNE 1982.

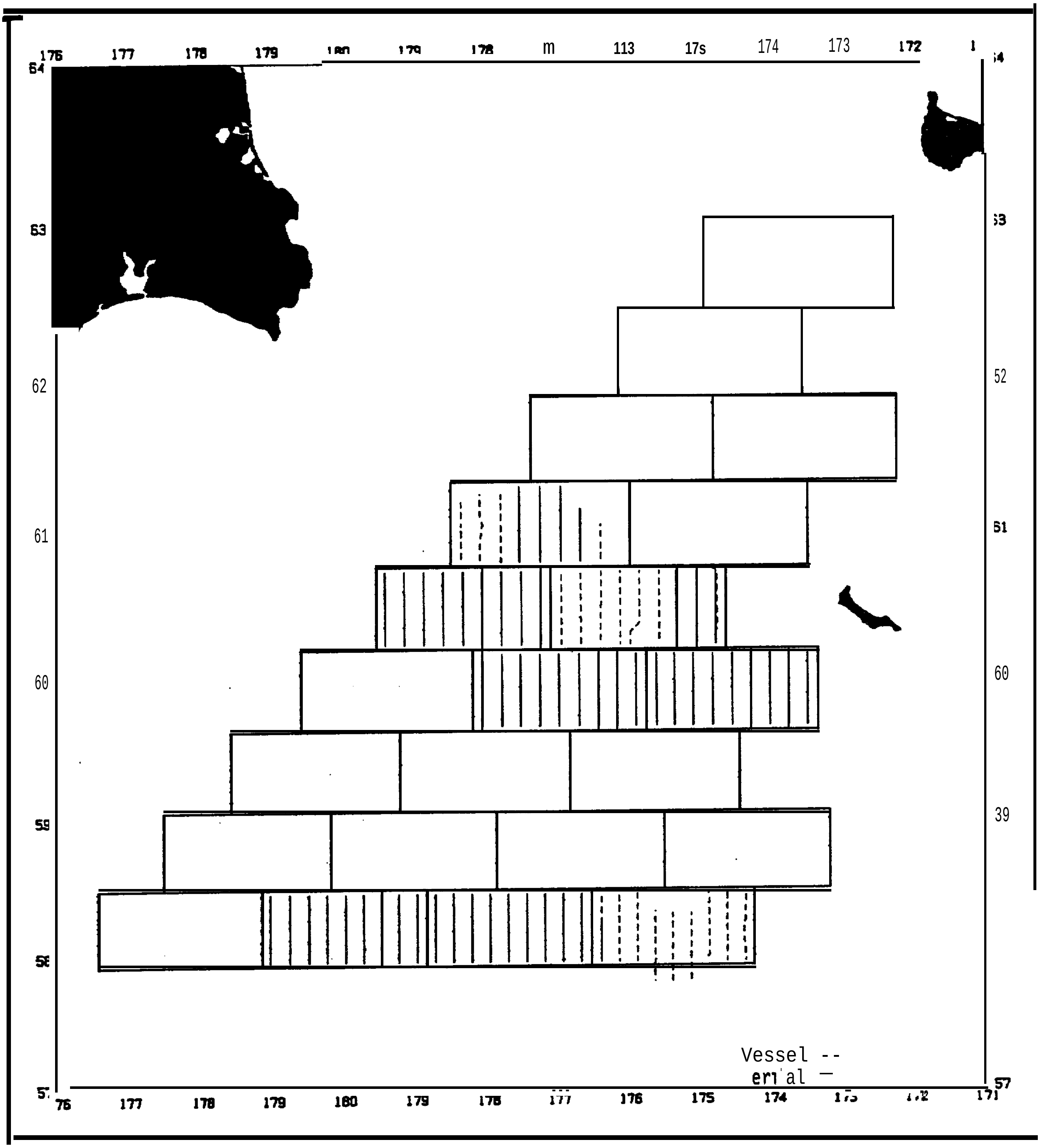
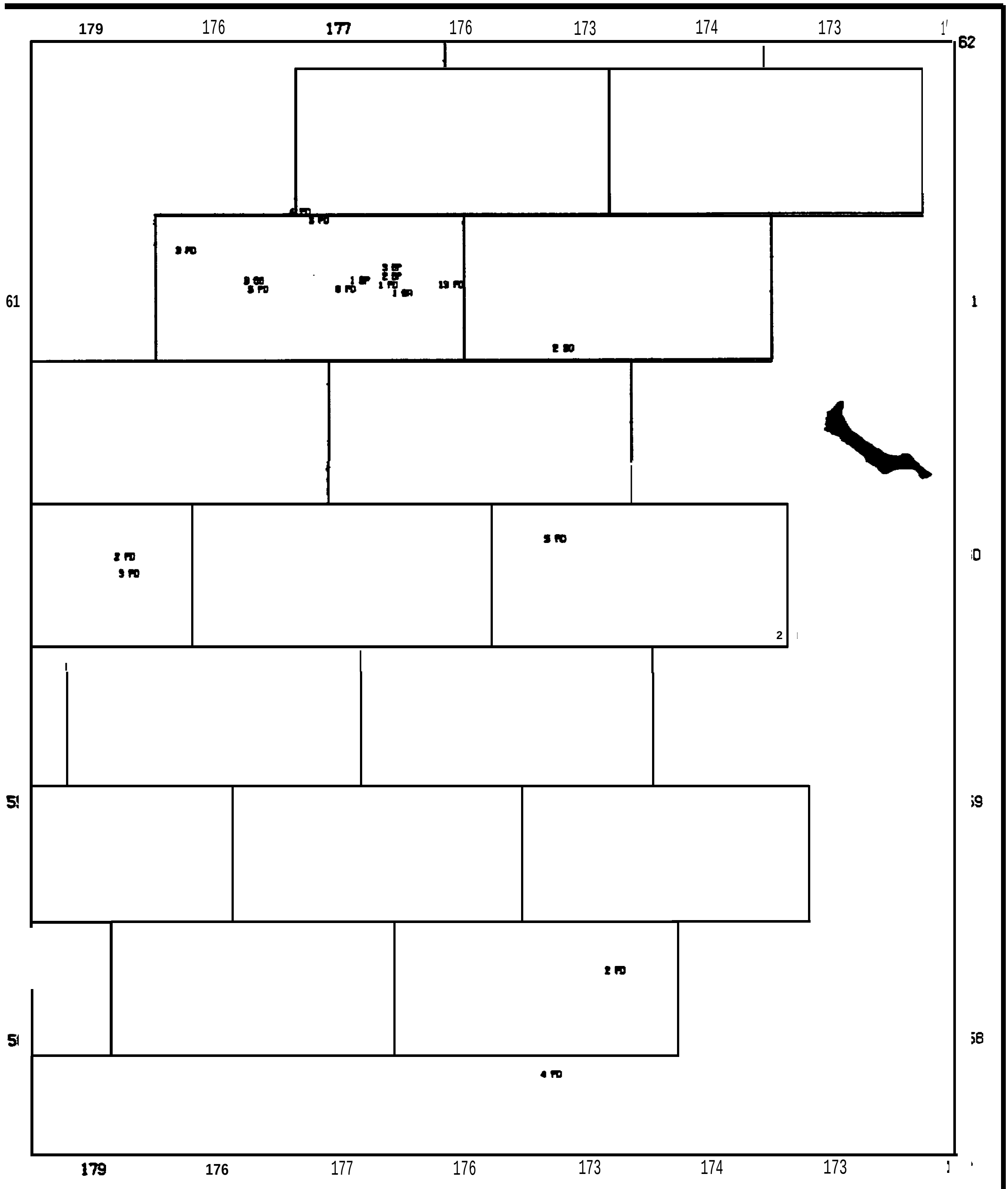


FIGURE 3 **LOCATION OF AERIAL AND VESSEL TRACKLINES SURVEYED IN THE NAVARIN BASIN DURING SUMMER, JULY- AUGUST 1982.**



IGURE 4 LOCATION OF WHALES OBSERVED IN THE NAVARIN BASIN DURING THE SUMMER SURVEYS, JULY - AUGUST 1982.

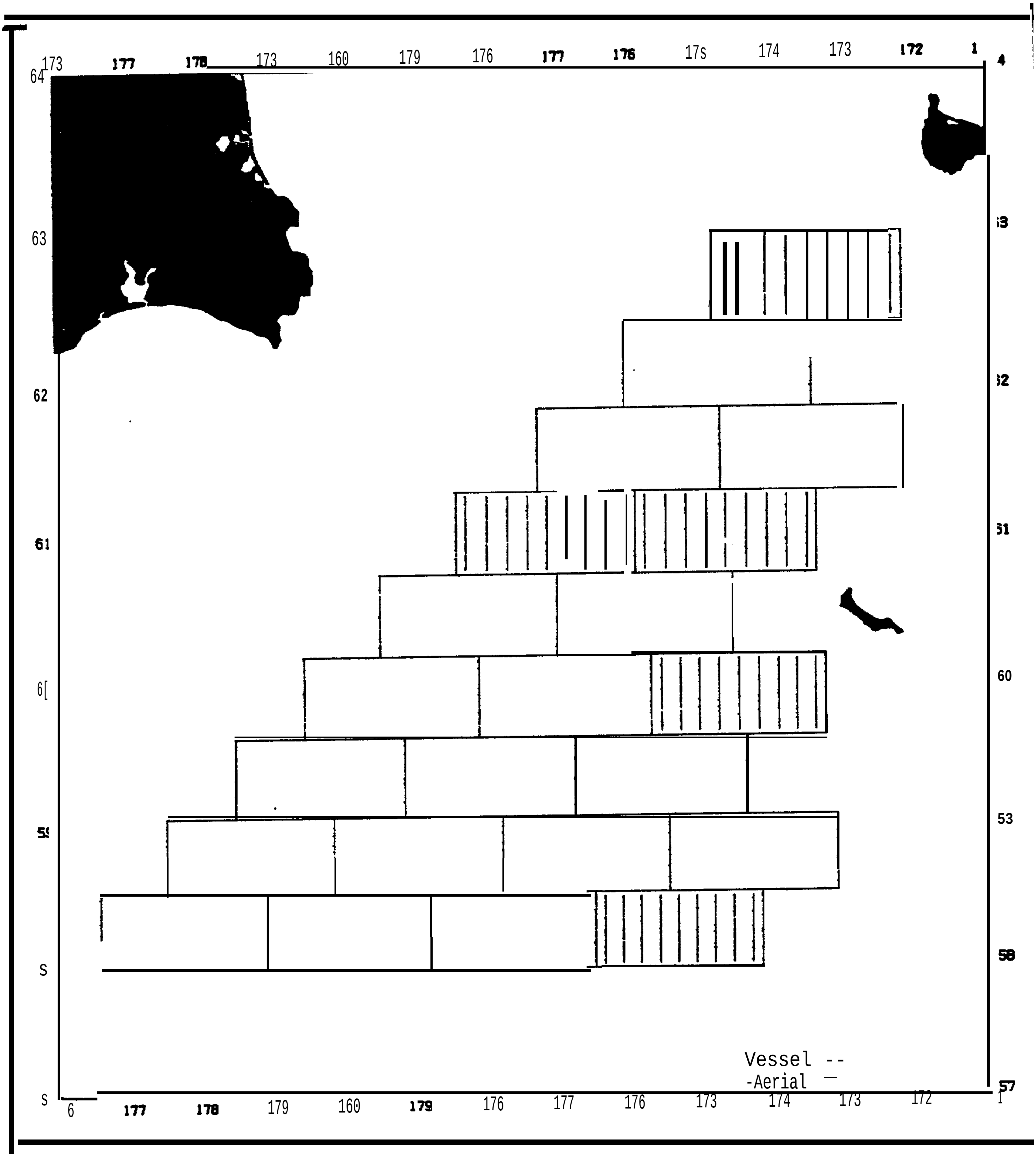


FIGURE 5 LOCATION OF AERIAL AND VESSEL TRACKLINES SURVEYED IN THE NAVARIN BASIN DURING FALL,OCTOBER–NOVEMBER 1982.

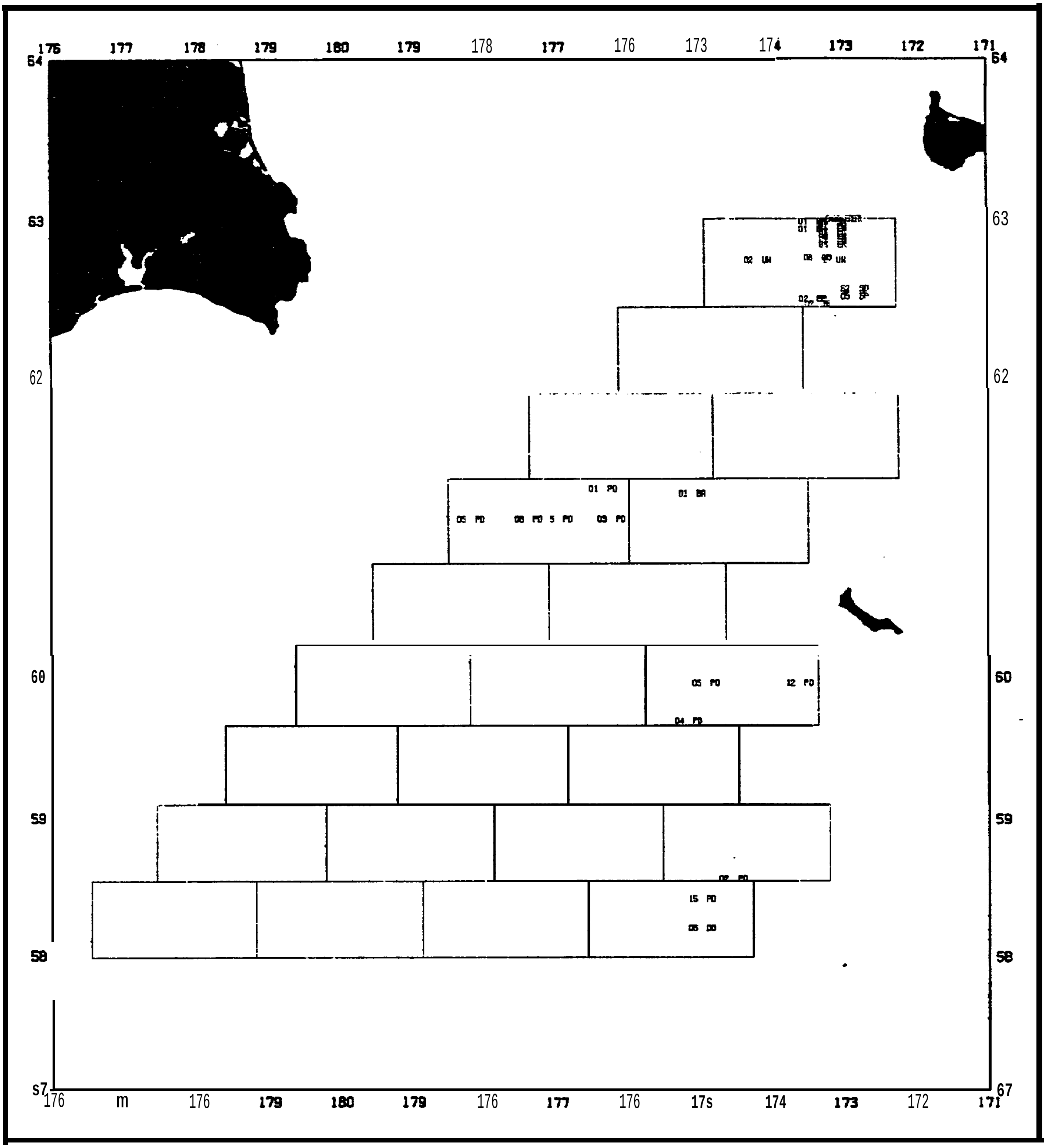
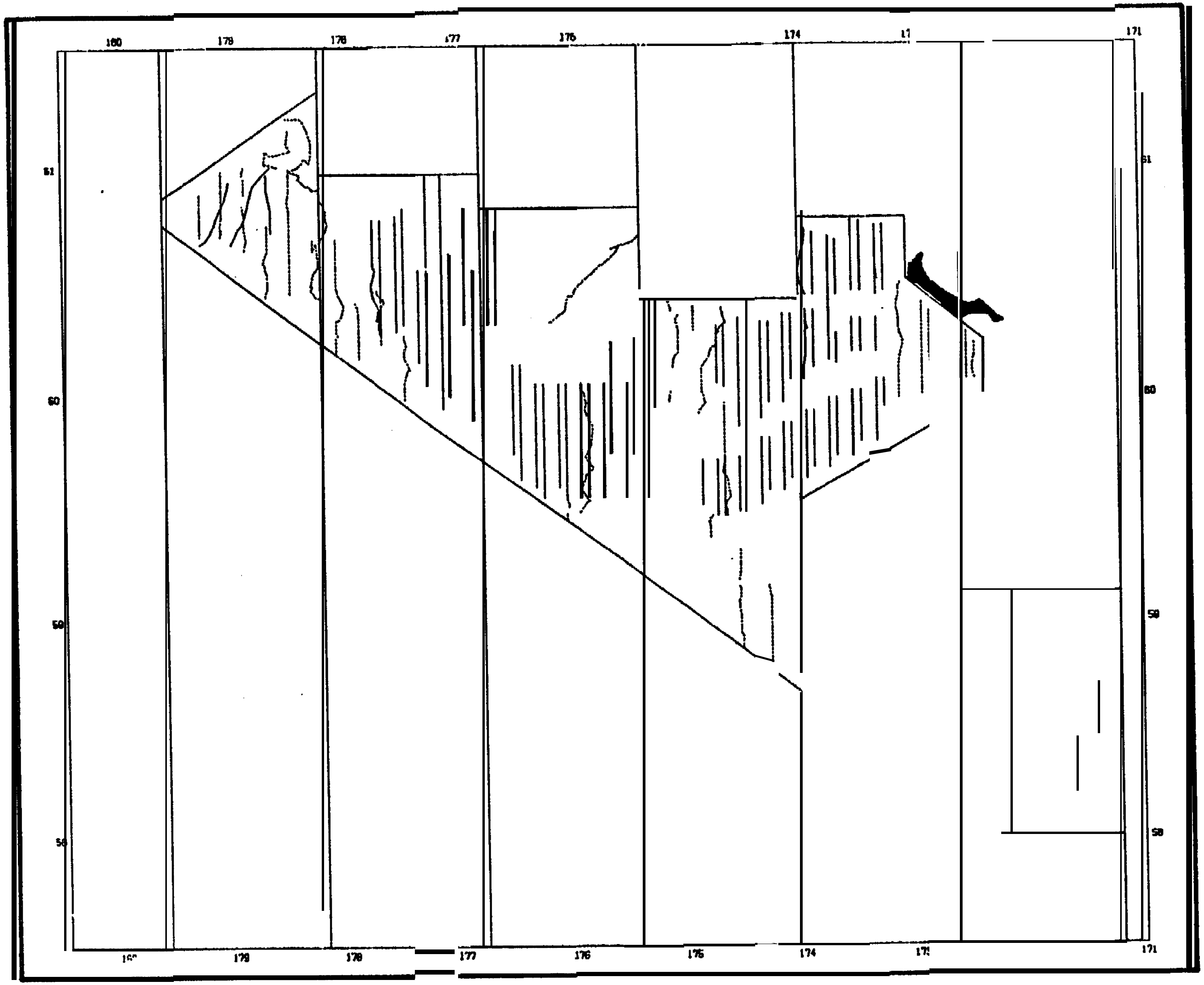


FIGURE 6 LOCATION OF WHALES OBSERVED IN THE NAVARIN BASIN DURING THE FALL SURVEY, OCTOBER-NOVEMBER 1982.



GURE 7 LOCATION OF AERIAL AND VESSEL TRACKLINES SURVEYED IN THE NAVARIN BASIN DURING WINTER, FEBRUARY - MARCH 1983.

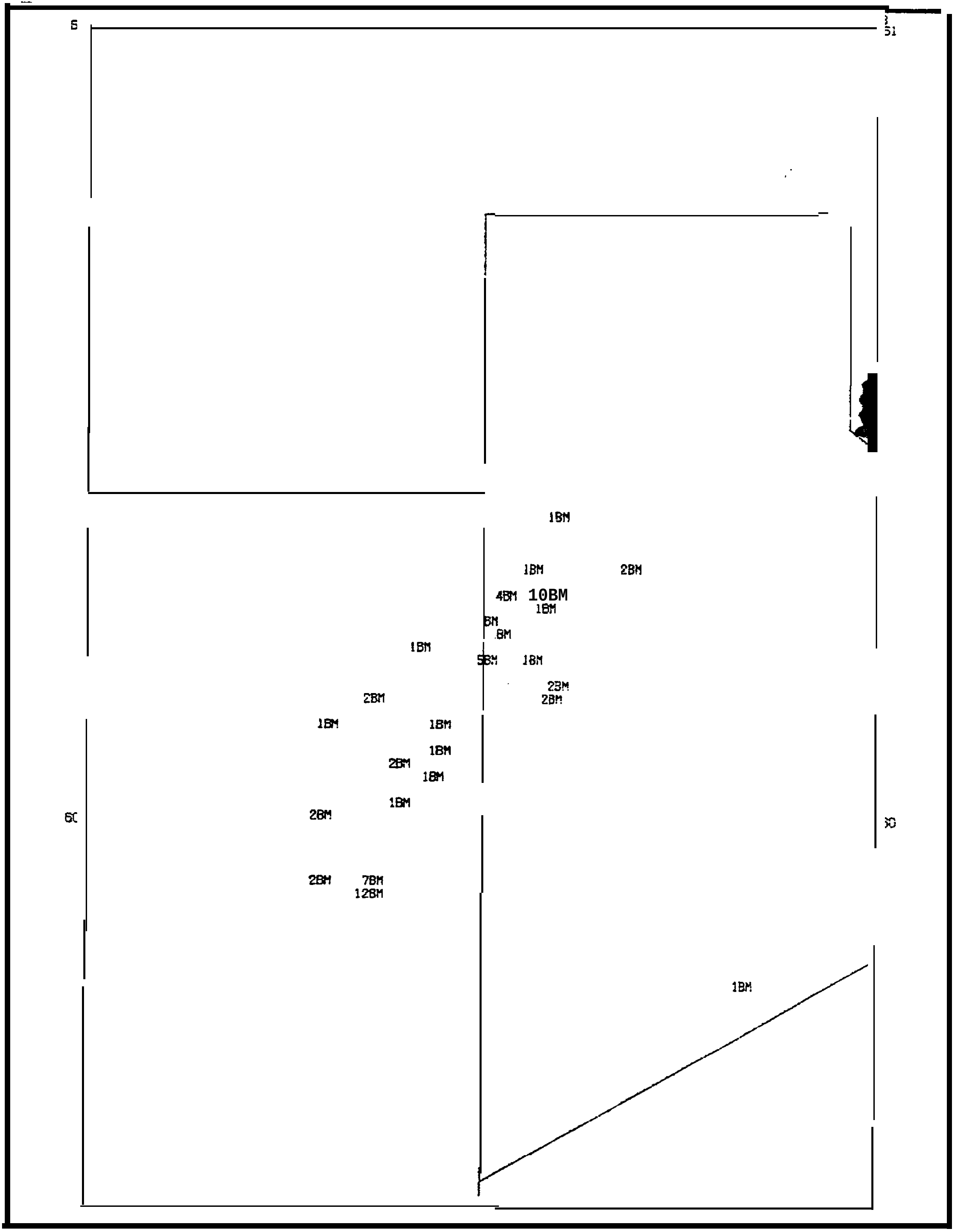


FIGURE 8 LOCATION OF WHALES OBSERVED IN THE NAVARIN BASIN DURING THE WINTER SURVEY, FEBRUARY - MARCH 1983 (includes duplicate sightings).

APPENDIX B

APPENDIX B

Line-transect theory was used to estimate densities and abundances of whales in the Navarin Basin as an alternative to the strip transect approach (Appendix Table B-l). Line-transect was not the primary method employed because the underlying assumptions of the theory may not have been met. The assumptions are:

1. Groups directly on the line will neverbe missed (i.e., they are seen with probability 1).

2. Groups are fixed at the initial sighting position; they do not move before being detected and none are counted twice.

3. Distances and angles are measured exactly; thus, neither measurement errors or rounding errors occur.

4. Sightings of groups are independent events.

Sample sizes achieved during the surveys were insufficient to test these assumptions. Sightability curves, developed from histograms of perpendicular sighting distances, indicated assumption 1 may have been violated (Figure B-l). Visibility of the line under the aircraft may have been obstructed since the sightability curves were not constantly decreasing functions. Small sample sizes may have contributed to the form of the curve; a larger sample size may have fit the data to a curve conforming to assumption 1. Failure to count all animals on the line (or in the strip for the strip transect method) underestimates the number of animals censused. Assumptions 2 and 3 are difficult to assess relative to the survey data; however, angles to animals were carefully measured by observers and flight patterns were designed to reduce duplicate counts of animals; whales certainly moved before they were seen. Because of difficulties in meeting the assumptions of line transect theory, and failure to obtain a minumum sample size of 40 observations (Burnham et al. 1980), the population estimates derived from this procedure should be viewed with caution, but are provided to show that alternative estimation approaches were applied to the data.

Line-transect sampling procedures were used to estimate numbers of fin, gray, and minke whales in each survey zone of the Basin (Table B-1). Pooled sighting data for gray, fin, and minke whales recorded during aerial surveys were used to estimate the essential parameter f(o), which is the sighting probability density function evaluated at a perpendicular distance of zero. Since the sightabilities of these whales are generally similar, the data were pooled to increase the sample size for estimating f(o). Sighting data for the other species of whales in the Basin or that data associated with the vessel surveys were not used in this analysis because of extremely small sample sizes of whale observations. The estimation of f(o) is described by Burnham et al. (1980).

For each species, the density of groups (D_{gi}) was calculated by sampling unit, then summed for each zone, i, as follows:

$$D_{gi} = \frac{n_i\ f(o)}{2L_i} \tag{1}$$

where: n_i = the number of groups observed during systematic surveys of transect lines in zone i.

f(o) = the pooled species sighting probability density at a perpendicular distance of zero.

L_i = the total transect line length in zone i.

The variance of group density was calculated as:

$$Var(D_{gi}) = (D_{gi})^2 \frac{Var(n_i)}{(n_i)^2} + \frac{Var\ f(o)}{f(o)^2} \tag{2}$$

$$\text{with } Var(n_i) = L \sum_{i=1}^{k} \frac{l_i \left[\frac{n_i}{l_i} - \frac{n}{L}\right]^2}{R} \tag{3}$$

where l_i = the length of individual transect line
R = the total number of transect lines

The density of individuals (D_{ii}) is calculated as:

$$D_{ii} = D_{gi}\bar{g} \tag{4}$$

where $\bar{g}$ = the mean group size for a particular species

The number of animals in each survey zone was estimated as:

$$N_i = D_{ii} A_i \tag{5}$$

where: A_i = area of a survey zone

The number of animals of each species was calculated as:

$$N = \sum_{i=1}^{k} N_i \tag{6}$$

where: k is the number of survey zones.

Its variance was estimated as:

$$Var(N) = (D_{gi})^2 Var(\bar{g}) + (\bar{g})^2 Var(D_{gi}) \tag{7}$$

where: $Var(\bar{g}) = \frac{Var(g)}{n}$

The variance of n_i ($Var(n_i)$) was estimated empirically using equation 1.24 (p. 54) of Burnham et al. (1980). The variance of f(o) is a theoretical variance calculated according to the particular sighting model. Equations (1), (2), and (3) are taken from Burnham et al. (1980), while equations (4) to (7) were developed by D.G. Chapman for special situations of the present aerial survey.

Approximately ninety-five percent confidence intervals for the estimates of N were estimated as follows:

$$\hat{N} \pm Z_{0.05}\sqrt{\widehat{Var}(\hat{N})}$$

Use of the Z statistic assumes the estimates are normally distributed; however, in view of the small sample sizes this is only approximately correct.

Program TRANSECT (Laake et al. 1979) was used to calculate f(o) for pooled data of fin, gray, and minke whales. For all cases, ungrouped sighting data were used for each species but all species were pooled and the Fourier series estimator of f(o) was used. The data were applied to numerous standard parametric estimators (normal, half normal, exponential, negative exponential, power series, etc.), but the Fourier series provided the best representation of all data sets. Moreover, this estimator is a non-parametric procedure that is model robust and pooling robust and its estimation efficiency for the small sample sizes is quite good (Burnham et al. 1980).

The line-transect estimates presented in Table B-1 are generally higher than the strip transect estimates. Although this is a typical characteristic of the line-transect procedure, differences between the two types of estimates were not significantly different, i.e., the estimates fell within the confidence intervals.

APPENDIX TA8LE B-1

ESTIMATED ABUNDANCE OF Endangered WHALES IN THE NAVARIN BASIN FROM LINE-TRANSECT SAMPLING PROCEDURE

Spec es[a]	Season	study area (nm^2) (A)	Transect length (nm) (L)	Number of groups (n_i)	Density (groups/ nm^2) (Dg_i)	Mean[b] group size (g)	Standard deviation of group size	Density (individuals/ nm^2) (Dii)	Abundance (N)	Variance (Var(N))	95 percent confidence interval for line transect	95 percent[c] confidence interval for strip transect
Fin whale	Spring	41,770	1,568	10	0.0049	2.37	1.16	0.0115	481	237,175	481+955	259+826
Fin whale	Summer	54,078	954	3	0.0012	2.37	1.16	0.0028	154	12,695	154+221	84+267
Fin whale	Fall	46,699	1,330	3	0.0017	2.37	1.16	0.0040	186	34,439	186+364	225+597
Gray whale	Fall	46,699	1,330	10	0.0056	2.44	1.98	0.0134	627	393,522	627+1299	500+1326
Minke Whale	Fall	46,699	1,330	2	0.0011	1	1	0.0011	51	1,279	51 +70	25+66

[a] Bowhead whale abundance was not estimated because the data poorly fit standard parametric (negative exponential, exponential, half-normal, etc.) and non-parametric (Fourier series) estimation models.

[b] Mean group size of fin whales did not differ significantly (F=3.31, 2, 31df, P 0.10) among seasons so the data were pooled to obtain a single group size figure.

[c] Abundance estimates from strip transect sampling procedure are included for comparison to those derived from line-transect sampling procedures.

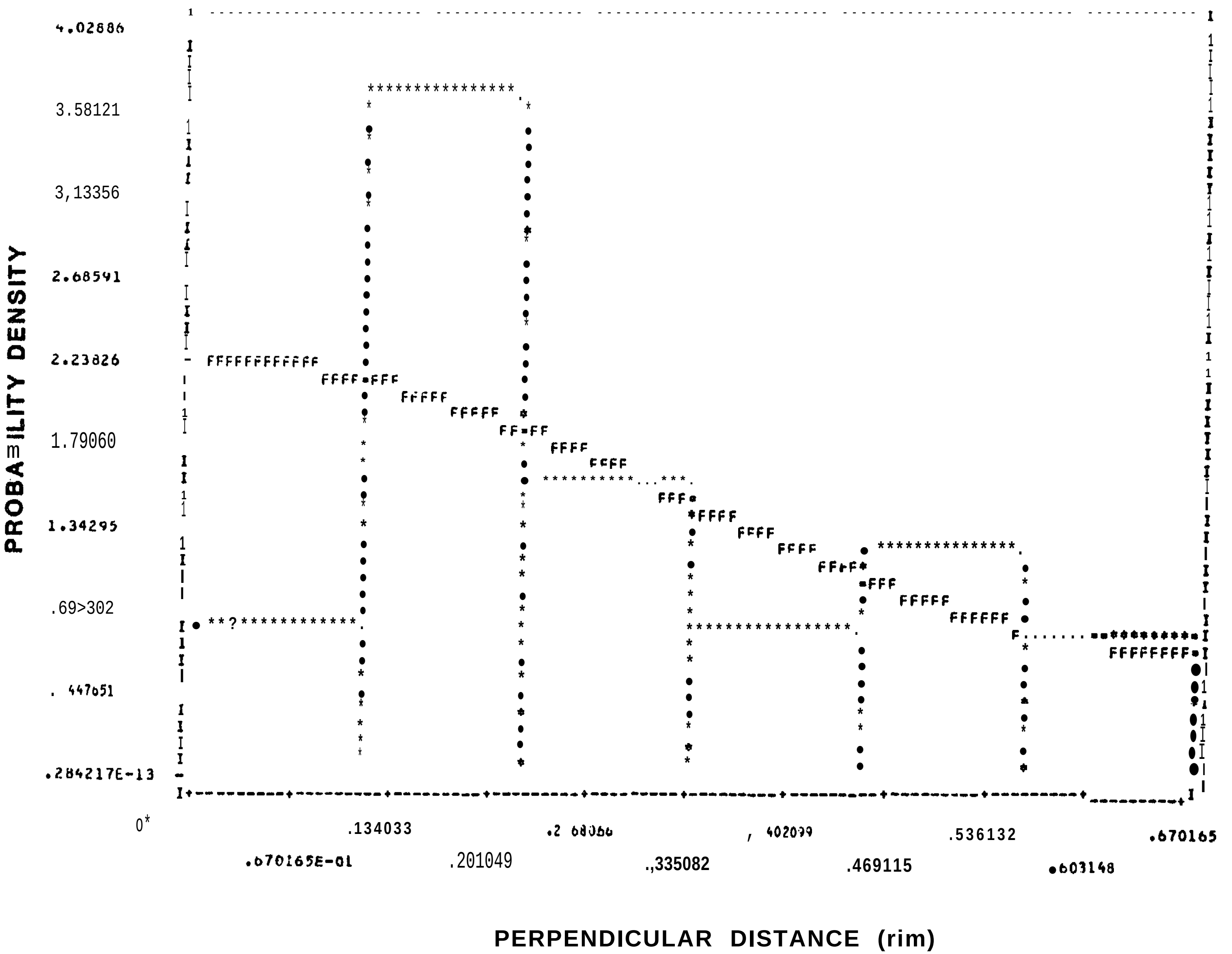


FIGURE 1 THE FOURIER SERIES ESTIMATOR OF THE PROBABILITY DENSITY FUNCTION OF PERPENDICULAR DISTANCE FIT TO THE HISTOGRAM OF THE DATA FOR ALL LARGE WHALE (FIN,GRAY,MINKE) SIGHTINGS.

APPENDIX C

APPENDIX C

INSTRUCTION MANUAL FOR HP-21C PROGRAM TO GUIDE HELICOPTER ON SURVEY TRACKLINES FROM VESSEL

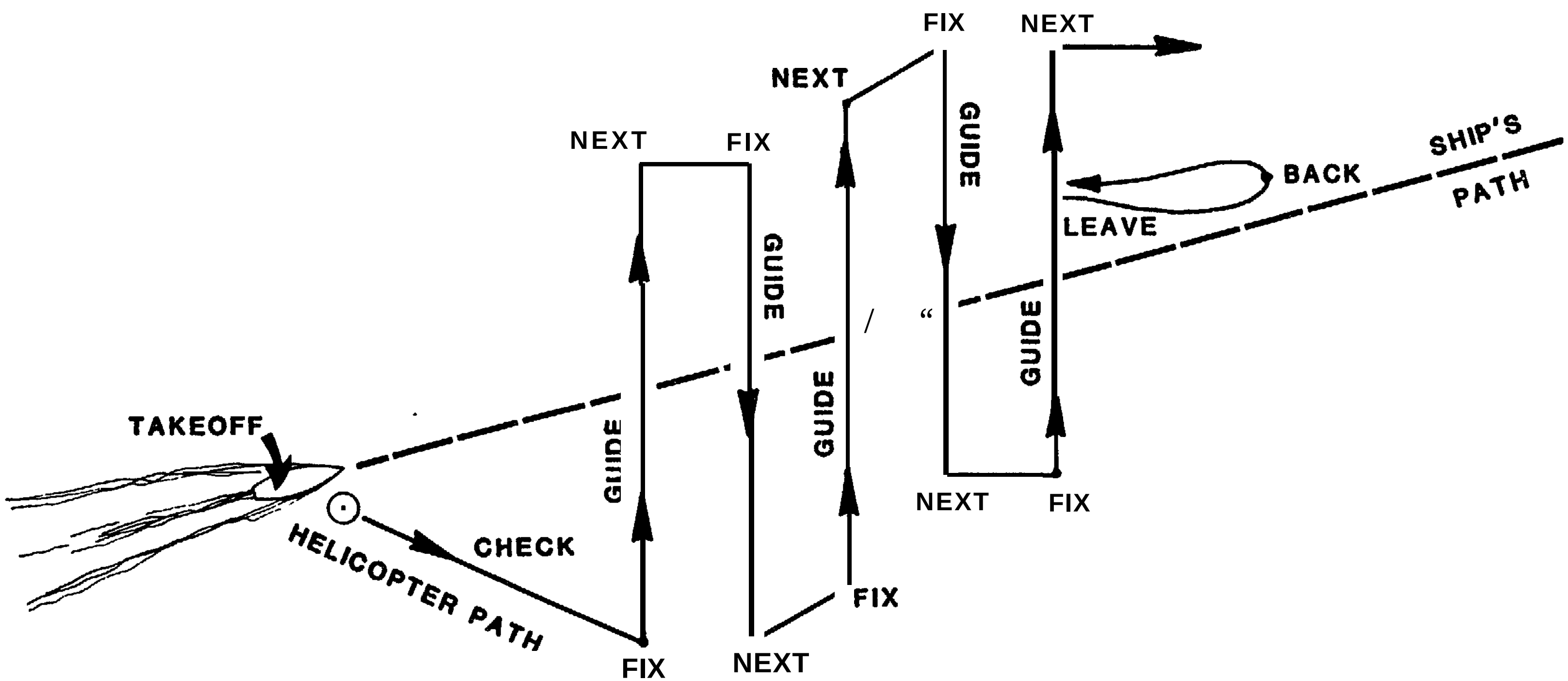
TABLE OF CONTENTS

I. INTRODUCTION

A series of programs was developed specifically for helicopter navigation during the 1983 winter aerial survey of endangered cetaceans in the Navarin Basin. Helicopter navigation systems (Loran C and radar) have broken down at critical times in past surveys, necessitating a reliable, independent navigation system. Since the tracklines are systematically placed within randomly chosen units, the helicopter must be guided along specific tracklines. Failure of the normal guidance systems, resulting in erratic survey tracklines, invalidates data collected. Thus, programs were developed to ensure a successful research effort.

The development and logic of the programs coincided with the sequence of conducting an aerial survey (Figure C-1). Independent of Loran C or radar guidance systems, the helicopter possesses instrumentation to determine the bearing and distance back to the ship and the ship knows its own location. Based on that information, plus time, ship speed and course, and helicopter speed, a tracking system was developed. The normal sequence of events during a survey is as follows: the helicopter takes off from the ship, proceeds to the start of the first survey trackline, travels north or south surveying mammals to end of trackline, and then flies east or west to the next survey trackline. The helicopter returns to the ship to end the survey and/or to refuel. During a flight, normal operations can be interrupted to resurvey a trackline or to investigate a sighting.

The observers in the helicopter may adjust the starting and ending locations of tracklines to survey within the proper habitat (i.e., marginal ice front).



After <u>TAKEOFF</u> from the vessel, the helicopter proceeds to the start of the trackline with its progress <u>CHECKed</u> along the way. Once there, its location is <u>FIXed</u> and it is <u>GUIDEd</u> along the trackline to the end. Then the helicopter is directed to the NEXT trackline's starting point where its location is again <u>FIXed</u>. This pattern is altered only when the helicopter <u>LEAVES</u> the trackline for a random search afterwhich it is guided BACK to that point of departure.

FIGURE 1 **STAGES OF INITIATION OF DIFFERENT PROGRAMS USED IN NAVIGATING HELICOPTER ALONG TRACKLINES DURING WHALE SURVEY.**

The programs were developed to run on a Hewlett Packard (HP) 21C programmable calculator with a quad memory module, time module, navigation module, and printer. A general understanding of how to operate the calculator, its modules, and accessories is necessary to fully understand this manual.

There are 319 registers available on the HP-41C with the quad memory module. There are 7 bytes per register. Size 070 is entered to reserve registers O through 70 for data storage and module subroutines. The first 19 registers are reserved for module subroutines, although actual module subroutines occupy only registers O through 10. After the program is stored, there are 23 of the total 379 registers left.

Programs produce the results on paper with time written as "NEW TIME" or "OLD TIME", so that log sheets can be filled in after completion of surveys. Also, the ship's location is output so that its path and the helicopter's path can be mapped during the surveys. All programs can be stored on magnetic cards to be reloaded if program memory fails.

The following procedures are necessary to operate the program:

1. At the start of a trackline and while on a trackline, the operator gives the helicopter a bearing to head for 3 minutes to be on trackline.

2. If helicopter is less than 3 minutes from the end of a trackline, the operator provides bearing and time to the end point.

3. If helicopter leaves the trackline for random or replicate search, the helicopter pilot gives bearing and distance from ship to calculator operator and says "leaving line".

4. On south and north replicate searches, operator initiates program "LEAVE", at which time helicopter turns 180° and searches the area. When done, helicopter radios its distance and bearing to ship and ship guides helicopter back to point of departure from trackline. If the helicopter wants to make several more passes along a section of trackline, it goes to the original point of departure and informs the operator that it is leaving the trackline for another replicate. If the helicopter wants the turning point locations documented, helicopter will say "FIX" to operator and observers will write the time in their logsheets and get the location when back on ship.

5. Only one helicopter is guided; a second must tag along.

6. Course of helicopter is stored before "GUIDE" or "NEXT" program are executed.

7. Beginning latitude (BL2) and longitude (BLO2), and ending latitude (EL2) and longitude (ELO2) of each 1 ine are always entered.

8. East longitude is entered as a negative number by operator.

11. DESCRIPTION AND OPERATIONOF PROGRAMS

A. DESCRIPTION OF PROGRAMS

"GUIDE"	Guides helicopter along trackline. Will give a heading to follow for 3 minutes. If less than 3 minutes to end of trackline, will notify helicopter. If greater than 3 minutes, will head helicopter straight back to trackline (east or west) and provide number of minutes to trackline.
"NEXT"	Given heading observers want to follow, provides number of minutes to start of next trackline and whether to head north or south when there.
"SHIP"	Gives location of ship at time indicated by words "NEWTIME".
"STD"	Converts speed of ship to distance.
"POS "	Calculates position of ship.
"HELI"	Gives position of helicopter at time indicated by words "NEMTIME" without storing it back in registers.
"HELIP"	Gives position of helicopter projected to where it will be when program execution stops.
"HELIR"	Gives position of helicopter at time indicated by words "NEWTIME" and stores it back in registers.
"PROJECT"	Used by program "HELIP" to take into account running time. Projects helicopter position to where it will be when program finishes.

"FIX"	Fixes location of an animal, trackline starting point, a turning point, or other notable marks. Outputs data on paper for later entry into logsheets.
"TAKEOFF"	Guides helicopter from ship to start of first trackline.
"OUTPUT"	Displays program results.
"NS"	Determines whether to head north or south on a trackline.
"CHECK"	Adjusts course from helicopter "TAKEOFF" to ensure starting point of trackline is reached.
"LEAVE"	Identifies location where helicopter leaves systematic trackline for replicate or random search.
"BACK"	Guides helicopter back to location recorded by "LEAVE".

B. INTERACTIONOF PROGRAMS

Program	Uses	Seconds to Run (should be tested on ship)
GUIDE	HELIP GC[a] GCPOS[a] NS	88
NEXT	HELIR GC[a] GCPOS[a]	77
SHIP	STD Pos	23
STD	None	
Pos	GCPOS[a]	
HELI	SHIP GCPOS[a]	
HELIP	SHIP GCPOS[a] PROJECT	
HELIR	SHIP GCPOS[a]	

[a] Denotes a subroutine of the HP navigation module for the HP-21C calculator.

Program	Uses	Seconds to Run (should be tested on ship)
PROJECT	GCPOS[a]	
FIX	HELI	31
TAKEOFF	SHIP GC[a] OUTPUT	42
OUTPUT	None	
NS	None	
CHECK	HELIP OUTPUT GC[a] NS	66
LEAVE	HELI	60
BACK	HELI GC[a]	55

C. VARIABLE LIST WITH STORAGE REGISTERS AND NOTES[a/]

Description	Variable	Register	Notes
Ship latitude (lat) source	SL1	17	d.d.
Ship longitude (long) source	SL01	18	d.d.
Ship course	SC	19	d.d
Ship speed	SS	20	knots
Calculated time helicopter (heli) to destination lat & long	TC	23	decimal minutes
Newtime (time when program executes)	NT	24	decimal hours
Oldtime (when SL1,SL01, first entered)	OT	25	decimal hours
Time difference of ship	TDS	26	
Time difference of heli	TDH	27	
Time of heli to end of trackline	TEL	28	minutes decimal
Distance of ship oldtime to newtime	DS	29	
Distance perpendicular trackline to heli	DP	30	used in GUIDE, NEXT
Distance heli must travel on hypotenuse	DH	31	
Distance from where DP intersects line to point where DH intersects line	DI	32	used in GUIDE, NEXT
Distance of heli to ship	DHS	33	
Distance of heli back to trackline after random or replicate	DB	34	
Distance of heli to beginning of trackline	DHB	35	

a/ n.m. = nautical miles; d.d. = decimal degrees; d.h. = decimal hours; d.m.s. = degrees minutes seconds; d.m. = decimal minutes; h.m.s. = hours minutes seconds. If input is needed in decimal the Hewlett Packard function HR must be executed after the h.m.s. or d.m.s. are entered.

Description	Variable	Resister	Notes
Heli source lat	HL1	38	d.d.
Heli source long	HL01	39	d.d.
Heli course	HC	40	stored as real d.d. true, output as d.m.s. magnetic.
Heli speed	HS	41	knots
Heli lat at newtime	HL2	42	d.d.
Heli long at newtime	HL02	43	d.d
Heli true bearing to ship	TB	44	stored as d.d., input & output as d.m.s.
Beginning lat of present line	BL1	47	d.d.
Beginning long of present line	BL01	48	d.d.
Ending lat of present line	EL1	49	d.d.
Ending long of present line	EL01	50	d.d.
Beginning lat of next line	BL2	51	d.d.
Beginning long of next line	BL02	52	d.d.
Ending lat of next line	EL2	53	d.d.
Ending long of next line	EL02	54	d.d.
Heading east or weston deadheads	EW	57	east=+1;west=-1
Heli heading north or south	NS	58	positive=north negative=south
Temporary storage	TEMP	59	
Distance	D	X 01	in GC outputs D,HI; in GCPOS outputs L2, L02

Heading	HI	Y 06	in GC outputs D,HI; in GCPOS outputs L2, L02
Source lat	L1	07	d.d.
Source long	101	08	d.d.
Destination lat	L2	09	d.d
Destination long	L02	10	d.d
Seconds to run "GUIDE"	SECG	60	
Seconds to run "NEXT"	SECN	61	
Seconds to run "CHECK"	SECC	63	
Special "LEAVE" lat	SPL	64	d.d, additional heli lat and long storage locations
Special "LEAVE" long	SPLO	65	
Declination	DECL	66	store this as d.d. (add declination when converting magnetic to true, and subtract declination when converting true to magnetic)
Left open for input of seconds to "HELIP"	SECH	67	
Heading to new line	HNL	68	assume given d.m.s. stored as d.d.
Trigonometric angle of HNL	THNL	69	d.d.

D. **OPERATIONOF PROGRAMS**

1. **Program TAKEOFF**

'**Description: Guides helicopter from ship to start of first trackline.**

Example:

Actual Program Output

```
          XEQ - TAKEOFF
NEWTIME=  "
                16.4019
OLDTIME=
                15.5741
DIFFERENCE=
                 0.4238
SPEED=
                10.0000
DISTANCE=
                 7.1059
NEW SHIP LAT=
                60.1759
NEW SHIP LONG=
               144.3923
NEWTIME=
                16.4019
HEAD D:M:S=
                68.4140
FOR N MINUTES=
                25.8717
SHIP: RUN CHECK PROG IN
HALF THIS TIME=
                12.9359
                MINUTES
```

Explanation

Input:

Initialize or update registers.

17-SL1	51-BL2
18-SL01	52-BL02
19-SC	53-EL2
20-ss	54-EL02
25-OT	57-E"
41-HS	60-SECG
47-BL1	61-SECN
48-BL01	63-SECC
49-E L1	66-DECL
50-EL01	

Response to program prompts.

None.

output: When all registers are filled and TAKEOFF is executed, the program shows the time the program was executed, the heading the helicopter should follow, the number of minutes the helicopter should follow the heading, and when the operator should check if the helicopter is going to reach the trackline starting location on time. Any changes in ship's course and speed should be changed by the operator as they occur throughout the flight.

Comments: The registers listed above should be filled prior to the helicopter taking off. The pilot should have provided the calculator operator the HS. The observers should have provided the calculator operator the survey lines and positions. The ship information must be obtained from the ship.

2. Program CHECK

Description: Adjusts course from TAKEOFF to make sure helicopter reaches starting point of trackline.

Example:

Actual Program Output		Explanation
XEQ - CHECK -		**Input:**
NEWTIME=		Initialize or update registers.
	18.0919	All are full from TAKEOFF. Must
OLDTIME=		change 47-BL1,49-EL1,51-BL2, and
	18.0558	53-EL2 if observers change starting
DIFFERENCE=		latitude due to changing ice
	0.0328	conditions.
SPEED=		
	10.0000	Response to program prompts:
DISTANCE=		HBEAR? Input bearing (d.m.s.) and
	0.5563	HDIST? distance (n.m.) from the
NEW SHIP LAT=		helicopter to the ship. (Not the
	60.1756	bearing from the ship to the
NEW SHIP LONG=		helicopter.) Hit R/S after each
	145.0919	entry.
NEWTIME=		
	18.0919	**output:** The program provides the heading
H BEAR?		(d.m.s) the helicopter should follow and
254.0000	RUN	for how long. Also whether the helicopter
H DIST?		should head north or south. When helicopter
18.0000	RUN	hits start of trackline, helicopter should
SECONDS=		prompt operator to run FIX program. Operator
	45.0000	should keep track of time.
PROJECTED DIST=		
	1.0625	
NEW HELI LAT=		
	60.2145	
NEW HELI LONG=		
	144.3419	
NEWTIME=		
	18.0919	
HEAD D:M:S=		
	73.1712	
FOR N MINUTES=		
	23.3264	
THEN HEAD		
	180.0000	

3. Program FIX

Description: Fixes position of the starting point of a trackline, an animal, a turning point, or other notable mark. Outputs data on paper for later entry into logsheets.

Example:

Actual Program Output	Explanation
XEQ - FIX -	**Input:**
NEWTIME=	Initialize or update registers.
18.2246	None, already filled automatically.
OLDTIME=	
18.0919	Response to program prompts:
DIFFERENCE=	H BEAR? Input bearing (d.m.s.) and
0.1528	H DIST? distance (n.m.) from the
SPEED=	helicopter to the ship. Hit R/S
10.0000	after each entry.
DISTANCE=	
2.5766	output: Outputs latitude and longitude
NEW SHIP LAT=	location and newtime on paper for later
60.1756	entry into logsheets. Operator should be
NEW SHIP LONG=	ready to prompt helicopter 3 minutes from
145.1431	newtime.
NEWTIME=	
18.2446	
H BEAR?	
270.0000 RUN	
H DIST?	
37.0000 RUN	
NEW HELI LAT=	
60.1735	
NEW HELI LONG=	
143.5951	
NEWTIME=	
18.2446	

4. Program GUIDE

Description: Guides helicopter along trackline. Will give a heading to follow for 3 minutes. Will notify helicopter when less than 3 minutes to end of trackline. If greater than 3 minutes will provide bearing to head helicopter straight back to trackline (east or west) and provide number of minutes to trackline.

Examples:

Actual Program Output When:

Greater than 3 minutes from line

```
            Q-GUIDE -
NEWTIME=
                19.3921
OLDTIME=
                19.3752
DIFFERENCE=
                 0.0129
SPEED=
                10.0000
DISTANCE=
                 0.2473
NEW SHIP LAT=
                60.0860
NEw SHIP LONG=
               143.5948
NEWTIME=
                19.3921
H BEAR?
     260.0000      RUN
H DIST?
      10.0000      RUN
SECONDS=
                90.0000
PROJECTED DIST=
                 2.1250
NEW HELI LAT=
                60.1146
NEW HELI LONG=
               143.4341
NEWTIME=
                19.3921
HELI GT 3 MINS
AWAY FROM LINE.
**************
FOLLOW -----
HEADING=
               270.0705
FOR N MINUTES=
                 5.7238
NAUTICAL MILES=
                 8.1087
```

Normal travel along line

```
            XEQ - GUIDE -
NEWTIME=
                19.3752
OLDTIME=
                19.3625
DIFFERENCE=
                 0.0127
SPEED=
                10.0000
DISTANCE=
                 0.2428
NEW SHIP LAT=
                60.0860
NEW SHIP LONG=
               143.5918
NEWTIME=
                19.3752
H BEAR?
     225.0000      RUN
H DIST?
       5.0000      RUN
SECONDS=
                90.0000
PROJECTED DIST=
                 2.1250
NEW HELI LAT=
                60.1438
NEW HELI LONG=
               143.5236
NEWTIME=
                19.3752
HEADING=
               300.1712
FOR N MINUTES=
                 2.9986
NAUTICAL MILES=
                 4.2481
```

Close to end of line

```
            XEQ - GUIDE -
NEWTIME=
                19.3625
OLDTIME=
                19.3424
DIFFERENCE=
                 0.0201
SPEED=
                10,0000
DISTANCE=
                 0.3348
NEW SHIP LAT=
                60.0860
NEW SHIP LONG=
               143.5848
NEWTIME=
                19.3625
H BEAR?
     180.0000      RUN
H DIST?
      16.0000      RUN
SECONDS=
                90.0000
PROJECTED DIST=
                 2.1250
NEW HELI LAT=
                60.2706
NEW HELI LONG=
               143.5927
NEWTIME=
                19.3625
CLOSE TO END
HEADING=
               354.3631
FOR N MINUTES=
                 2.0591
NAUTICAL MILES=
                 2.9170
```

Explanation

Input:

Initialize or update registers.

None, already filled automatically.

Response to program prompts:

H BEAR? Input bearing **(d.m.s.) and H DIST?** distance **(n.m.) from the helicopter to** the **ship.** Hit R/S **after each entry.**

Output: Program provides heading to follow, number of minutes to **follow** heading, and number of nautical miles to **trackline.**

5. Program NEXT

Description: Given heading observers want to follow, provides number of minutes to start of next line and whether to head north or south when there.

Example:

Actual Program Output	Explanation
XEQ - NEXT -	**Input:**
NEWTIME= 15.0427	Initialize or update registers. Under all conditions 51-BL2, 52-BLO2, 53-EL2, and 54-ELO2 must have been entered. The rest are already filled.
OLDTIME= 14.4314	Response to program prompts:
DIFFERENCE= 0.2113	H BEAR? Input bearing (d.m.s.) and
SPEED= 10.0000	H DIST? distance (n.m.) from the helicopter to the ship. Hit R/S after each entry.
DISTANCE= 3.5349	HEADINGTO NEW LINE? Input heading (d.m.s.) observers want pilot to follow to next line relative to ice conditions.
NEW SHIP LAT= 60.1760	
NEW SHIP LONG= 144.0708	
NEWTIME= 15.0427	output: Provides number of minutes to reach new line and whether to head north or south when there. Then prompts operator to view leg and store information for next trackline.
H BEAR? 180.0000 RUN	
H DIST? 13.0000 RUN	**Comments:** After this run is completed, new values must be input for registers 51-54 by storing (STO) information from registers 47-50 into registers 51-54, respectively.
NEW HELI LAT= 60.3060	
NEW HELI LONG= 144.0708	
NEWTIME= 15.0427	When leaving a deadhead between tracklines for a random search, LEAVE and BACK programs must be executed after program NEXT. Once back to deadhead trackline NEXT must be executed again.
HEADING TO NEW LINE? 90* 0000 RUN	
MINUTES TO NEW LINE= 11.9011	
THEN HEAD 180.0000	
SHIP,VIEW LEG AND ENTER NEXT	
RCL 47 *** 60.5166	
RCL 48 *** 143.5000	
RCL 49 *** 60.0166	
RCL 50 *** 143.5000	

6. Program LEAVE

Description: Identifies position left from systematic trackline for replicate or random search.

Example:

Actual Program Output	Explanation
EQ - LEAVE -	**Input:**
NEWTIME=	Initialize or update registers.
21.0550	None, all are already filled.
OLDTIME=	
21.0223	Response to program prompts:
DIFFERENCE=	H BEAR? Input bearing (d.m.s.) and
0.0327	H DIST? distance (n.m.) from the
SPEED=	helicopter to the ship. Hit R/S
10.0000	after each entry.
DISTANCE=	
0.5740	**output:** The program outputs the helicopter
NEW SHIP LAT=	location and time.
60.1746	
NEW SHIP LONG=	**Comments:** The operator must wait for
146.0842	helicopter to supply bearing and distance
NEWTIME=	to head back to initial point of departure
21.0550	from systematic trackline.
H BEAR?	
245.0000 RUN	
H DIST?	
60.0000 RUN	
NEW HELI LAT=	
60.4221	
NEW HELI LONG=	
144.1733	
NEWTIME=	
21.0550	

7. Program BACK

Description: Guides helicopter to location recorded by LEAVE.

Example:

Actual Program Output		Explanation
	BA	input:
NEWTIME=		Initialize or update registers.
	21.0652	None, all are already filled.
OLDTIME=		
	21.0550	Response to program prompts:
DIFFERENCE=		HBEAR? **Input bearing (d.m.s.) and**
	0.0102	H **DIST? distance (n.m.)** from the
SPEED=		helicopter to the ship. **Hit R/S**
	10.0000	**after each entry.**
DISTANCE=		
	0.1726	**output: Gives helicopter's present location**
NEW SHIP LAT=		**and the heading and number of minutes back to**
	60.1746	**its LEAVE location.**
NEW SHIP LONG=		
	146.0902	**Comments: Operator must remind pilot to**
NEWTIME=		**circle** and wait until directions are given
	21.0652	on how to return **to** LEAVE location.
H BEAR?		Operator should also note time helicopter
247.0000	RUN	will arrive back on line (LEAVE location)
H DIST?		and be ready to prompt pilot and execute
61.5000	RUN	GUIDE or NEXT programs.
NEW HELI LAT=		
	60.4058	
NEW HELI LONG=		
	144.1325	
NEWTIME=		
	21.0652	
HEAD D:M:S=		
	304.3159	
FOR N MINUTES=		
	1.7326	

8. Program SHIP

Description: Execute SHIP and the program outputs ship's new latitude and longitude.

```
PRP 'FIX"

01♦LBL 'FIX"
62 XEQ "HELI"
03 END
```

```
01♦LBL 'US"
02 RCL 47
03 RCL 49
04-
05 STO 58
06 X<0?
07 GTO 01
08 GTO 02

09♦LBL 01
10 360
11 GTO 03

12♦LBL 02
13180

14♦LBL 03
.15 END
```

```
01♦LBL ● OUTPUT"
02 X<>Y
03 S10 48
04 X<>Y
85 RCL 41
06 1/X
07 *
08 60
09 *
10 S10 23
11 RCL 40
12 RCL 66
13-
14 CLA
15 "HEAD D:M:S="
16 AVIEW
17 HMS
18 VIEW X
19 RCL 23
28 CLA
21 "FOR N MINUTES="
22 AVIEW
23 VIEW x
24 END
```

```
01♦LBL "PROJECT*
02 RCL 41
03 *
04 60
05 ⁄
06 60
07 /
08 STO 01
09 RCL 40
10 S10 06
11 RCL 09
12 STO 07
13 RCL 10
14 STO 08
1S XROM "*GCPOS"
16 ENI
```

```
01♦LBL "STD"
02 TIME
03 HR
04 STO 24
05 RCL 25
06 RCL 24
07 RCL 25
08 -
09 STO 26
10 RCL 26
11 RCL 20
12 *
13 STO 01
14 END
```

```
PRP 'SHIP"

01♦LBL "SHIP"
K RCL 17
03 STO 07
04 RCL 18
05 STO 88
06 RCL 19
07 STO 86
08 XEQ ● sTr
09 XEQ "POS"
10 END
```

```
01♦LBL 'CIECK'
82 RCL 63
03 STO 67
84 XEQ "HELIP"
05 RCL 42
06 STO 87
07 RCL 43
08 STO 88
09 RCL 47
10 STO 09
11 RCL 48
12 STO 10
13 XROM "*GC"
14 XEQ "OUTPUT"
15XEQ"lls"
16 STO 40
17 RCL 66
18 -
19 HMS
28 CLA
21 "THEN HEAD"
22 AVIEW
23 VIEW X
24 END
```

```
PRP "LEAVE"

01♦LBL "LEAVE"
02 XEQ "HELI"
03 RCL 89
84 STO 64
85 RCL 10
06 STO 65
07 END
```

```
01♦LBL "BACK"
02 XEQ "HELI"
03 RCL 09
04 STO 07
85 RCL 10
06 STO 88
87 RCL 64
08 STO 09
09 RCL 65
10 STO 18
11 XROM "*GC"
12 XEQ WJTPUT
13 END
```

```
01♦LBL "TAKEOFF"
82 XEQ "SHIP"
03 RCL 17
04 STO 07
85 RCL 18
06 STO 08
07 RCL 47
08 STO 09
09 RCL 48
10 STO 10
11 XROM "*GC"
12 XEQ "OUTPUT"
13 CLA
14 "SHIP: RUN CHECK"
15 "⊦ PROG IN"
16 AVIEW
17 CLA
18 "HALF THIS TIME="
19 AVIEW
282
21 /
22 VIEW X
23 CLA
24 "
25 "⊦ MINUTES"
26 AVIEW
27 END
```

```
01♦LBL ● pos-
82 XROM "*GCPOS"
03 CLA
04" NEW SHIP LAT="
05 AVIEW
06 RCL 09
07 HMS
08 VIEW. X
09 CLA
10 "NEW SHIP LONG="
11 AVIEW
12 RCL 10
13 HMS
14 VIEW X
15 CLA
16 "NEWTIME="
17 RCL 24
18 HMS
19 AVIEW
28 VIEW X
21 RCL 09
22 STO 1?
23 RCL 10
24 STO 18
25 RCL 24
26 STO 25
27 END
```

```
PRP "HELI"

01♦LBL "HELI"
02 XEQ 'SHIP"
03 "H BEAR?"
04 PROMPT
05 RCL 66
06 HMS
07 HMS+
08 HR
09 STO U
10 180
11 -
12 STO 86
13 "H DIST?"
14 PROMPT
15 STO 33
16 STO 01
17 RCL 17
18 STO 07
19 RCL 10
28 STO 08
21 XROM "*GCPOS"
22 CLA
23 "NEW HELI LAT="
24 AVIEW
25 RCL 09
26 HMS
27 VIEW X
28 CLA
29 "NEW HELI LONG="
30 AVIEW
31 RCL 10
32 HMS
33 VIEW X
34 CLA
35 "NEWTIME="
36 RCL 24
37 HMS
38 AVIEW
39 VIEW X
40 END
```

```
PRP "HELIP"

01♦LBL "HELIP"
02 XEQ "SHIP"
03 'H BE AR?"
04 PROMPT
05 RCL 66
06 HMS
07 HMS+
08 HR
09 STO 44
10 180
11 ÷
12 STOW
13 "H DIST?"
14 PROMPT
15 STO 33
16 STO 01
17 RCL 17
18 STO 07
19 RCL 18
28 STO $8
21 XROM "*GCPOS"
22 RCL 67.
23 XEQ "PROJECT"
24 CLA
25 'HEW HELI LAT="
26 AVIEW
27 RCL 09
28 HMS
29 VIEW X
38 CLA
31 "NEW HELI LONG="
32 AVIEW
33 RCL 10
34 HMS
35 VIEW X
36 CLA
37 "NEWTIME="
38 RCL 24
39 HMS
40 AVIEW
41 VIEW X
42 RCL 09
43 STO 42
44 STO 38
45 RCL 10
46 STO 43
47 STO 39
48 END
```

```
PRP "HELIR"

01♦LBL "HELIR"
82 XEQ 'SHIP"
03 'H BEAR?"
04 PROMPT
05 RCL 66
06 HMS
07 HMS+
08 HR
09 STO 44
10 180
11 -
12 STO 06
13 "H DIST?"
14 PROMPT
15 STO 33
16 STO 01
17 RCL 17
18 S10 07
19 RCL 18
28 STO 138
21 XROM "*GCPOS"
22 CLA
23 "NEW HELI LAT="
24 AVIEW
25 RCL 09
26 HMS
2? VIEW X
28 CLA
29 "NEW HELI LOHL="
38 AVIEW
31 RCL 10
32 HMS
33 VIEW X
34 CLA
35 "NEWTIME="
36 RCL 24
37 HMS
38 AVIEW
39 VIEW X
40 RCL 89
41 STO 42
42 STO 38
43 RCL 10
44 STO 43
45 STO 39
46 END
```

```
PRP "NEXT"

01+LBL "NEXT"
92 XEQ ● HELIR-
83 "HEADING TO.
04 "├NEW LINE?"
K PROMPT
06 RCL 66
87 +
08 HR
89 ENTER?
10 90
11-
12 ENTER↑
13-1
14 *
1S S10 69
16 RCL 42
17 S10 67
18 S10 09
19 RCL 43
28 STO 08
21 RCL 52
22 STO 10
23 XROM "*GC"
24 STO 38
25 RCL 57
26 *
27 STO 38
28 RCL 69
29 TAN
30 *
31 STO 32
32 X>0?
33 GTO 04
34180
3S GTO 05

36+LBL 04
37 360

38+LBL 65
39 STO 86
40 RCL 32
41 ABS
42 STO 01
43 RCL 42
44 STO 07
4S RCL 52
46 STO 68
47 XROM "*GCPOS"
48 RCL 42
49 STO 07
58 RCL 43
51 STO 08
52 RCL 09
53 STO 47
54 RCL 10
55 STO 48
56 STO 58
57 XROM "*GC"
58    RCL 41
59 1/X
60 *
6168
62 ●
6368
64 *
65 RCL 61 "
66-
6768
68 /
69 CLA
78 "MINUTES TO NEW "
71 "├LINE="
72 AVIEW
73 VIEW X
74 CLA
75 'THEM HEAD"
76 AVIEW
77 RCL 51
78 RCL 53
79-
88 STO 58
81 X<0?
82 GTO 01
83 GTO 02

84+LBL 01
85 360
86 GTO 03

87+LBL 02
88180

89+LBL 03
90 STO 40
91 RCL 66
92-
93 HMS
94 VIEW X
95 RCL 58
96 X<0?
97 GTO 10
98 "*5
99 GTO 11

100+LBL 10
101 .5

102+LBL 11
103 RCL 47
104 +
105 STO 49
106 CLA
107 "SHI ,VIEW LEG"
108 AVIEW
109 CLA
110 "AND ENTER NEXT.
1 1 AVIEW
1 2 END
```